THE EFFECTS OF PROBLEM-SOLVING ACTIVITIES USING DYNAMIC GEOMETRY COMPUTER SOFTWARE ON READINESS FOR SELF-DIRECTED LEARNING

By

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TABLE OF CONTENTS

Page

ACKNOWLEDGMENTS....ii

ABSTRACT....vi

CHAPTERS

1 INTRODUCTION....1

- Purpose of the Study....1
- Background Information....2
- Importance of the Study....6
- Proposed Model....6
- Research Questions....8
- Description of the Study....9
- Limitations of the Study....11
- Definitions of Terms....12
- Summary....13

2 REVIEW OF RELATED LITERATURE....15

- Self-directed Learning....15
- Self-Directed Learning Readiness Scale....31
- Dynamic Geometry Computer Software and the Constructivist Approach to Learning Mathematics....39
- Summary....44

3 METHODOLOGY....46

- Research Questions....46
- Instruments....49
- Population....52
- Sample....52
- General Procedure....53
- Data....57
- Data Analysis....57
- Summary....60

4 ANALYSIS OF THE DATA 62

Results 62
Readiness for Self-directed Learning 62
Performance in Geometry 71
Attitude towards Mathematics 72
Attitude towards Computers 77
Summary 82

5 SUMMARY AND CONCLUSIONS 85

Overview of the Study 85
Findings 86
Discussion 89
Implications 92
Replication of the Study 92
Recommendations 93
Summary 95

APPENDICES

A SAMPLE ACTIVITY WORKSHEETS AND SKETCHPAD FILES 97

B ATTITUDE TOWARDS THE GEOMETER'S SKETCHPAD SURVEY 112

REFERENCES 114

BIOGRAPHICAL SKETCH 120

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of the University of Florida in Partial Fulfillment of the
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The purpose of this study was to explore the relationship between computer technology and an individual's readiness for self-directed learning. Specifically, the study focused on the effects of problem-solving activities using dynamic geometry computer software on readiness for self-directed learning. Attitude towards the learning of mathematics, the use of computers, and their mediating effects were also explored. Seven intact geometry classes in a local high school participated in the study. Six of the classes were designated as the experimental group and received the experimental treatment. The other class served as the control group. Students in the experimental group visited the mathematics computer laboratory once a week for a period of six weeks. In the laboratory they received a set of problem-solving activities that were designed to be used with The Geometer's Sketchpad.

The Self-Directed Learning Readiness Scale (SDLRS), Computer Attitude Scale (CAS), and the Fennema-Sherman Mathematics Attitudes Scales were used to measure change in students' readiness for self-directed learning, attitude towards mathematics, and attitude towards computers. A measure of students' attitude towards The Geometer's Sketchpad was also used. Class grades for all the participating students were gathered for the grading period encompassing the period of study.

Analysis of variance, analysis of loglikelihood, correlations and multiple regression techniques were used to analyze the data. The results of the study ($p < .05$) do not indicate that problem-solving activities using dynamic geometry computer software had a direct effect on readiness for self-directed learning, on attitude towards mathematics or attitude towards computers. However, attitude towards The Geometer's Sketchpad and interaction between attitude towards computers and attitude towards The Geometer's Sketchpad were found to be significant covariates in a model of the change in SDLRS scores.

The results of this study indicate a positive relationship between the use of dynamic geometry computer software and readiness for self-directed learning through the mediating effects of attitude towards dynamic geometry computer software. The notion that the tools, including computer-based tools, that are available to the learner affects their readiness for self-directed learning merits further study.

CHAPTER 1
INTRODUCTION

> Experiences designed to foster continued intellectual curiosity and increasing independence should encourage students to become self-directed learners who routinely engage in constructing, symbolizing, applying, and generalizing mathematical ideas. Such experiences are essential in order for students to develop the capacity for their own lifelong learning and to internalize the view that mathematics is a process, a body of knowledge, and a human creation. (NCTM, 1989, p. 128)

This quote illustrates that there is currently a great emphasis on developing students' ability for self-directed learning. This is not a new idea or concern, nor is it confined to the realm of mathematics learning. What is new is the technology now available to help advance this ideal. The ever increasing infusion of computer technology into education helps promote images of "technology-rich classroom environments" that introduce a "new classroom dynamic in which teachers and students become natural partners in developing mathematical ideas" (NCTM, 1989, p. 128) speak of true fundamental change in the learning of mathematics. The merits of various forms of this technology — particularly calculators and computers — in the learning of mathematics constitute the center of many a study, discussion and debate.

Purpose of the Study

The purpose of this study was to explore the relationship between computer technology and an individual's readiness for self-directed learning.

Specifically, the study focuses on the effects of problem-solving activities using dynamic geometry computer software on readiness for self-directed learning. Attitude towards mathematics, attitude towards computers, and their mediating effects were also explored.

Background Information

The focus of this discussion will be the possible influences on an individual's readiness for self-directed learning. As in any human endeavor, "it is the personal characteristics of the learner — including his attitudes, his values, and his abilities — which ultimately determine whether self-directed learning will take place in a given learning situation" (Guglielmino, 1977, p. 34). The attitudes, values and abilities that constitute an individual's readiness for self-directed learning indicate that it is a function of many factors or variables. One of the independent variables in this function is the tools available to the learner. To illustrate the effect of tools, imagine how your attitudes, values and abilities would change if you no longer had pencil and paper or any other tool to simply record information. The possibilities in any human endeavor are determined by the mind and the tools available to the mind.

The learning of mathematics very often includes the analysis and interpretation of data. When paper and pencil are the only tools available, the gathering of the data may not be a simple task. For example, when trying to investigate the relationship between the graphs of $f(x)$ and $f(x + c)$, many examples must first be generated. Those using pencil and paper must have considerable ability, time and patience in graphing various functions to generate the necessary data before any pattern recognition or analysis can be performed. The ability to graph functions becomes an end rather than a means to an end. A major advantage of computer technology is that it allows the learner to generate the needed data — the graphs — quickly and efficiently, and thus reduces the step of gathering data to a minor one; this allows for the major focus to be on decision making as to which data are needed, and the subsequent interpretation and analysis of that data. Various computer-based tools have been developed that do much of the mechanical calculations, measurement, and graphical and symbolic manipulation needed in mathematical investigations. These range from simple graphing software to more versatile programs such as Maple, MathCad and Mathematica.

Dynamic geometry software is one type of computer-based mathematics tool that has become increasingly popular in mathematics education, particularly in secondary school geometry. This type of software allows for direct construction, manipulation, and measurement of geometric figures. The Geometer's Sketchpad, developed by Nicholas Jackiw and the Visual Geometry Project at Swarthmore College, is an example of dynamic geometry software and was used in the study. As described by Lyn Taylor, "Sketchpad gives the user electronic versions of Euclid's tools — a point tool, a compass and a straightedge" (Taylor, 1992, p. 187). A simple example of its use is the construction of a triangle by drawing three connecting segments with the straightedge tool. The user can then dynamically create other triangles by grabbing and moving one of the vertices with the mouse. The triangle will be automatically redrawn as the chosen vertex is moved. By selecting the vertices and accessing the options in the "Measure" menu, the measure of any of the angles can be displayed and automatically updated as the triangle is manipulated. In a similar manner, the sum of the measures of all three angles can be calculated. The user, in a short period of time and with minimal effort and training, can now generate a literally infinite number of example triangles, each including the measure of each angle, and the sum of the measures of each angle, which of course equals 180°. By doing this construction and manipulation, the users conduct their own investigation into the sum of measures of the angles of a triangle and come to the natural conclusion that the sum is always equal to 180°.

Dynamic geometry software dramatically increases a student's ability to gather adequate data, in terms of quantity (i.e. number of examples) and quality (i.e. accuracy of measurement and calculations) needed in an investigation of a concept. This in turn increases the students' ability to, and likelihood of, determining for themselves what information is to be gathered, testing their own hypotheses, deciding what is to be learned and how. These are essential ingredients for successful self-directed learning of mathematics. The use of such technology in the learning of mathematics also emphasizes learning activities that reflect a constructivist perspective. According to Davis, Maher and Noddings (1990), hypothesizing, trying things out, executing mathematical procedures, communicating and defending results, and reflecting on the methods used and conclusions reached are, from a constructivist perspective, the activities that are "part of what it means to engage in mathematics. Learning mathematics requires construction, not passive reception, and to know mathematics requires constructive work with mathematical objects in a mathematical community" (Davis et al, 1990, p. 2). This illustrates the notion that constructivism is closely related to self-direction in learning (Candy, 1991). Both incorporate the theme of learners as active participants in the managing of their own learning actions. Confrey goes so far as to claim that "personal autonomy is the backbone of the process of construction" (Confrey, 1990, p. 111).

Even though self-direction has been a "recurrent concern of educators in all ages, in most cultures, and for all levels" (Candy, 1991, p. xiv), various definitions for self-directed learning have been proposed in the past; even alternate labels such as "self-regulated learner" have been used. Malcolm Knowles describes self-directed learning as "that process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes" (Knowles, 1975, p. 18). To help identify and quantify an individual's readiness for self-directed learning, Guglielmino developed The Self-Directed Learning Readiness Scale (SDLRS). The SDLRS has been widely used and is generally regarded as "the instrument to measure self-direction in learning" (Landers, 1989). Overall, the SDLRS has been use by "more than 500 major organizations" and given to "more than 40,000 adults and 5,000 children" and translated into nine other languages (Guglielmino & Guglielmino, 1995).

In its present form, the SDLRS consists of 58 statements of learning preferences and attitudes towards learning as described by the instructions to the user. Each item incorporates a five-point Likert scale. Both positive statements ("I love to learn") and negative statements ("I'll be glad when I'm finished learning") are included. The user is asked to give one of five possible responses to each statement. The possible responses range from "Almost never true of me; I hardly ever feel this way" at one end, to "Almost always true of me; there are very few times when I don't feel this way" on the other. Each response is given a score from one to five and a total score is derived from summing the score of each item. A higher score is indicative of a greater readiness for self-directed learning.

Importance of the Study

Using Knowles' view of self-directed learning, a scientist doing research is in essence a self-directed learner. Here computer technology can "transform the mathematics classroom into a laboratory" where students "perform independent investigations . . . and use technology to investigate, conjecture and verify their findings" and "provides opportunities for students to summarize ideas and establish connections with previously studied topics" (NCTM, 1989, p. 128). If such a learning environment is to be established, then a logical conjecture is that an emphasis on self-directed learning and the use of computer technology must become a natural part of that environment. Equating the learner with a scientist can be seen as a major goal of mathematics education.

Such a conjecture needs some empirical evidence to help guide and encourage the development of learning environments that emphasize self-directed learning as well as the integrated use of computer technology. This study was designed to provide some of that evidence.

Proposed Model

This study examined the influence of problem-solving activities using dynamic geometry computer software on an individual's readiness for self-directed learning. Others factors influencing an individual's readiness for self-directed learning studied are attitude towards mathematics and computers. Mathematics learning experiences can affect an individual's attitude towards mathematics and the learning of mathematics. Likewise, experiences with using computers can affect an individual's attitude towards computers and using computers. Therefore, learning experiences with computer-based mathematics tools can not only directly affect an individual's readiness for self-directed learning, but can also affect it indirectly by influencing attitude towards mathematics and computers, which in turn may affect individuals' readiness for self-directed learning. The ultimate objective of improving an individual's readiness for self-directed learning as well as their attitude towards mathematics and the use of computers in the learning of mathematics is to improve their achievement in the learning of mathematics.

This proposed model of the relationships between experience with computer-based mathematics tools, attitude towards mathematics and the learning of mathematics, attitude towards computers and using computers, and an individual's readiness for self-directed learning and mathematics achievement is illustrated in Figure 1-1.

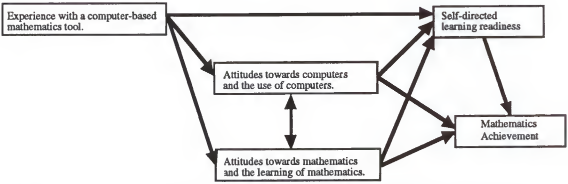
Experience with a computer-based mathematics tool.
Self-directed learning readiness
Attitudes towards computers and the use of computers.
Mathematics Achievement
Attitudes towards mathematics and the learning of mathematics.

Figure 1 - 1. Proposed Model of Relationships Between Variables Studied

The model above only includes those factors explored in this study. There are certainly other factors which affect each of the components in the model. These will be identified as "outside factors" and be included as residual variables in the analysis of the data.

Research Questions

The research questions that were addressed by this study are listed below. Following each question is a general statement of the hypotheses pertaining to that question that were statistically tested. An expanded list of questions and hypotheses can be found in the Research Questions section in Chapter 3.

1. Will doing problem-solving activities using dynamic geometry computer software (i.e. the Geometer's Sketchpad) make a difference in a student's readiness for self-directed learning?

   Hypotheses: There is no significant difference in the change in Self-Directed Learning Readiness Scale (SDLRS) scores between students grouped by experimental treatment, teacher, class period, grade or gender.

2. Will doing problem-solving activities using dynamic geometry computer software (i.e. the Geometer's Sketchpad) make a difference in a student's performance in geometry?

   Hypotheses: There is no significant difference in grades received in the geometry course between students grouped by experimental treatment.

3. Will doing problem-solving activities using dynamic geometry computer software (i.e. the Geometer's Sketchpad) make a difference in a student's attitude towards mathematics?

   Hypotheses: There is no significant difference in the change in Fennema-Sherman Mathematics Attitudes Scales scores between students grouped by experimental treatment, teacher, class period, grade or gender.

4. Will doing problem-solving activities using dynamic geometry computer software (i.e. the Geometer's Sketchpad) make a difference in a student's attitude towards computers?

Hypotheses: There is no significant difference in the change in Computer Attitude Scale scores between students grouped by experimental treatment, teacher, class period, grade or gender.

5. How are experience with computer-based mathematics tools, attitude towards mathematics and the learning of mathematics, attitude towards computers and using computers, and an individual's readiness for self-directed learning and mathematics achievement related to each other?

   Hypotheses: There is no significant difference in the change in SDLRS scores between students grouped by experimental treatment due to interaction effect of experimental treatment and ability in geometry, attitude towards mathematics, attitude towards, and/or attitude towards The Geometer's Sketchpad.

Description of Study

The participants in this study were students enrolled in seven geometry classes at a high school in Gainesville, Florida. At the beginning of the study, the participants completed a set of surveys that measure individuals' readiness for self-directed learning and attitude towards mathematics and computers. The instruments used were the Self-Directed Learning Readiness Scale (SDLRS), Computer Attitude Scale (CAS), and the Fennema-Sherman Mathematics Attitudes Scales. The investigator gathered additional information — grade, sex, teacher, and class period — for each student.

Six of the classes visited the mathematics computer laboratory, once a week for a period of six weeks. In the laboratory, they received a set of problem-solving activities that were designed to be used with The Geometer's Sketchpad. These activities were designed by the investigator with input from the participating teachers. They were designed to coincide with the topics and concepts that were covered in the regular classroom activities during subsequent days. They were also designed around the notion that "sometimes it is not the problem itself that is important, but rather the thought, analysis, and techniques necessary for its solution" (Milauskas, 1987, p. 73). The participants worked in teams of two, and at their own pace. Worksheets contained descriptions of the problems and were used by the students to record their answers and how they arrived at them. Sketchpad files specifically designed for a problem or set of problems served as a starting point. Each file contained a sketch and/or progressive hints to aid in the solving of a given problem. Participants were free to manipulate and modify the sketch in any way that they deemed necessary or desirable. The hints were viewed and used or ignored as seen fit. The worksheets and Sketchpad files were authored by the investigator with input provided by the participating teachers. See Appendix A for examples of worksheets and Sketchpad files.

At the end of the six-week period, the SDLRS, CAS and the Fennema-Sherman Mathematics Attitudes Scales were administered a second time, to the experimental and control classes. An informal survey of attitude towards The Geometer's Sketchpad was administered to the six classes that received the Sketchpad activities. Class grades for all the participating students were gathered for the grading period encompassing the period of study. They included the quarter grades for that term and grades for the semester final given at the conclusion of that term. Average grades in the course for the year were calculated.

Descriptive statistics (mean, standard deviation, etc.) for each of the variables were calculated as well as correlations between the various attitude scales to test for redundancy. Multiple regression models were constructed to identify those variables that significantly explain the variation in the dependent variable (SDLRS scores).

Limitations of the Study

This study contained limitations that affect the generalizability of the results. This study was conducted with high school students enrolled in geometry courses at one high school. Classes as a whole were assigned as part of the experimental or control group by choice of the teacher. This meant that students were not randomly assigned to experimental treatment and control groups. Only one class out of the seven in the study was assigned to the control group and the other six to the experimental group, therefore the experimental and control were not equal in size.

The problem-solving activities were developed by the investigator and designed around the topics that were covered in the classroom and the textbook in use during the course of the study. One of the classes assigned to the experimental group was using a different textbook and had only a partial overlap of topics covered with the other classes. Due to this, this class did not receive exactly the same problem-solving activities as the other experimental classes.

The teachers' class schedule limited the visits to the computer laboratory to once a week. Only one software program from the set of software programs that fall under the label of dynamic geometry software was used. The results of this study are generalizable to situations involving similar stimuli and classes of variables.

Definition of Terms

Self-directed learning has several definitions (see Chapter 2). In this study, Knowles' definition self-directed learning as "that process in which individuals take the initiative, with or without help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes" was used (Knowles, 1975, p. 18).

Dynamic geometry software refers to a class of mathematics software that allows for direct construction, manipulation, and measurement of geometric figures. The Geometer's Sketchpad, developed by Nicholas Jackiw and the Visual Geometry Project at Swarthmore College, is an example of dynamic geometry software and was used in the study.

The Self-Directed Learning Readiness Scale (SDLRS) is a widely used measurement of an individual's readiness for self-directed learning.

The Fennema-Sherman Mathematics Attitude Scales are ten separate scales designed to measure some domain-specific attitudes related to the learning of mathematics by all students. Three of the scales were used in this study, Confidence in Learning Mathematics, Mathematics Anxiety Scale, and the Effectance Motivation in Mathematics Scale.

The Computer Attitude Scale (CAS) is designed to measure attitude toward computers and their use. The scale includes three subscales: computer anxiety, computer confidence and computer liking.

Constructivism as related to the learning of mathematics refers to the view of mathematics as *invented* or *constructed* by human beings, rather than an independent body of truths or an abstract and necessary set of rules. (Goldin, 1990, p. 31)

Summary

There is currently a great emphasis on developing students' ability for self-directed learning. This is certainly true in the area of mathematics learning. There is also currently an increased emphasis on the development of computer-based mathematics tools that are designed to enhance students' ability and desire to explore mathematics, construct mathematical knowledge, and communicate their mathematical understanding to others.

This chapter presents the rationale for a study designed to explore the relationships between computer technology and an individual's readiness for self-directed learning. The study focused on the effects of problem-solving activities using dynamic geometry computer software on readiness for self-directed learning. Attitude towards mathematics, attitude towards computers, and their mediating effects were also explored. Background information, importance of the study, a proposed model of the relationship between relevant variables, general research questions and a description of the study have been outlined.

Chapter 2 contains a review of literature pertaining to the questions of interest. It focuses on a theoretical framework for self-directed learning, the development and use of the Self-Directed Learning Readiness Scale (SDLRS) and the incorporation of dynamic geometry computer software in the environment for the study of geometry. It includes a focus on constructivism as a link between self-directed learning and dynamic geometry computer software. A discussion of the methodology and study design is found in Chapter 3. Chapter 4 presents the analysis of the data gathered during the study. A discussion of the conclusions, implications and recommendations drawn from the study is contained in Chapter 5.

CHAPTER 2
REVIEW OF RELATED LITERATURE

This study explores the effects of problem-solving activities using dynamic geometry computer software on readiness for self-directed learning. A review of relevant literature follows and will focus on three main areas. The first is a theoretical framework for self-directed learning. The second is on the development and use of the Self-Directed Learning Readiness Scale (SDLRS). The third is the incorporation of dynamic geometry computer software in the environment for the study of geometry; this area focuses on constructivism as a link between self-directed learning and dynamic geometry computer software.

Self-directed Learning

To understand the concept of self-directed learning, one can start by examining its definition. Knowles defines self-directed learning as "that process in which individuals take the initiative, with or without help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes" (Knowles, 1975, p. 18). This definition is often quoted in literature on self-directed learning (Guglielmino, 1977, 1991; Piskurich, 1993; Long, 1990; Candy, 1991). Other definitions include: "A systematic process in which an individual takes responsibility, in collaboration with others, for diagnosing his or her own learning needs, formulating learning objectives, planning and engaging in a sequence of learning experiences to achieve these objectives, and evaluating progress toward these objectives" (Shafritz, Koeppe, & Soper, 1988, p. 424); "any study form in which individuals have primary responsibility for planning, implementing and even evaluating the effort" (Husén & Postlethwaite, 1994, p. 5394); and "that of the learner's own choosing and not provided by a formal educational system. See also open education, random learning" (Page & Thomas, 1977, p. 306).

Candy (1991) states that the term "self-direction" has been applied to four different phenomena: personal autonomy, will and ability to manage one's own learning, independent pursuit of learning without formal institutional support or affiliation, and the mode of organizing instruction in a formal setting (learner control). The term itself has various forms or equivalents. Long not only quotes Knowles' definition, but applies the same definition to the term "learner managed learning" (Long, 1990). Piskurich states that the terms individualized instruction, prescriptive learning, self-instructional packages, programmed learning, computer-mediated instruction, contract learning, computer-based training, interactive video, and a "dozen other terms" can be used interchangeably with self-directed learning. The entry for "self-directed learning" in the index of the International Encyclopedia of Educational Technology points the reader to "see independent study" (Eraut, 1989). Under the heading of "Self-Directed Learning" in the Education Index is "see Motivational Learning."

The most common term that equates to self-directed learning is self-regulated learning. Zimmerman (1989) defines self-regulated learning as related to the degree to which students are "metacognitively, motivationally, and behaviorally active participants in their own learning process" (p. 4). This also incorporates the main theme of learners as active managers and directors. The following discussion draws on literature on self-directed learning and self-regulated learning.

Though there are certainly terms and definitions that greatly differ from Knowles' definition, most center around the theme of learners as active participants in the managing of their own learning actions. As Grow states that "few people have ever defined self-directed learning with precision; nonetheless, self-directed learning is an immensely useful concept for orienting oneself to education at all levels" (Grow, 1991, p. 128).

The concept of self-directed learning is unquestionably not new. Even though it has "recently been captured" by the field of adult education, it has been a "recurrent concern of educators in all ages, in most cultures, and for all levels" (Candy, 1991, p. xiv). In ancient Greece, self-study played an important part in the lives of Socrates, Plato, Aristotle (Husén & Postlethwaite, 1994). In classical Rome, the teacher had the "trivial role" of imparting the *trivium* so that learners could then "get on with the important business of self-education" (Candy, 1991, p. xiv). In the nineteenth century, self-directed learning became popular as artisans and aristocrats "embarked on programs of self-improvement and cultural advancement" (Candy, 1991, p. xiv). In the first half of the nineteenth century, George Craik advocated self-directed learning and documented the self-education efforts of several people (Candy, 1991; Husén & Postlethwaite, 1994). In 1830 Craik wrote: "The truth is, that even those who enjoy to the greatest extent the advantages of what is called a regular education must be their own instructors as to the greater portion of what they acquire, if they are to advance beyond the elements of learning. What they learn at schools and colleges is of comparatively small value, unless their own after-reading and study improve those advantages" (Candy, 1991, p. 5). In 1859 Smiles published *Self-Help* which is now considered "legendary" (Candy, 1991). According to Candy, interest in self-directed learning "has ebbed and flowed in the 20th. century" but as stated by others, it has intensified in recent years (Candy, 1991, Husén & Postlethwaite, 1994).

Why is it important for learners to be self-directed? Much of the literature on self-directed learning is related to life-long learning, the notion that learning is an important and essential part of an adult's life as well as a child's life. Many educators feels as Knowles states, that it is "no longer realistic to define the purpose of education as transmitting what is known. In a world in which the half-life of many facts (and skills) may be ten years or less . . . the main purpose of education must now be to develop the skills of inquiry" (1975, p. 15). In such a rapidly changing world, it is becoming increasingly normal for an individual to have two, three, or more career changes in a normal work life of thirty to forty years (Long, 1990). This may necessitate a return to a formal educational setting. It also is recognized that learning is not restricted to formal educational settings. Many professionals, such as those in the medical profession, must keep current in their field (Shulman, 1994). They must rely on their own initiative and resources to educate themselves. Many adults who work full time feel the need or desire to advance their skill level or knowledge in one area or another to improve their chances for advancement in their current field, or to switch to a more desirable field of work. However, sometimes their formal educational opportunities are constrained by their busy schedules (Husén & Postlethwaite, 1994). Most adults (estimates up to 98%) are said to be regularly involved in "independently undertaking self-initiated learning activities outside formal education institutions" (Candy, 1991, p. 52). Such considerations reinforce the desire and need for "life-long learning" for most, if not all, members of a modern, changing society. Self-directed learning is seen as a key, if not the key, to life-long learning, and must be instilled in learners even before they become adults (Candy, 1991; Della-Dora & Blanchard, 1979, Dirkes, 1993; Knowles, 1975; Long, 1990).

Practical considerations such as life-long learning needs are not the only ones in support of self-directed learning; philosophical and pedagogical considerations are many times also given. Some see self-directed learning as incorporating and promoting essential values to be instilled in members of a present and future democratic society. These values include the "democratic ideal, the ideology of individualism, the concept of egalitarianism, the subjective or relativistic epistemology, the principles of humanistic education and the construct of education" (Candy, 1991, p. 47) "In a democratic society, students need to have opportunities to learn how to choose *what* is to be learned, *how* it is to be learned, *when* it is to be learned, and *how to evaluate* their own progress" (Della-Dora & Blanchard, 1979, p. 1). Others see self-directed learning as an essential component in fostering the ideals and values of learning. Smeeth (1994) states that self-directed learning is the highest level of learning possible. Some "seek to understand and nurture the development of [self-regulated learning] attitudes in order to prevent students from rejecting the values of education, devising shortcuts to complete assignments, and setting minimal performance goals" (Paris & Byrnes, 1989, p. 169).

A key notion is that self-directed learning empowers students. This occurs by having students take increasingly more responsibility for various decisions associated with learning (Husén & Postlethwaite, 1994). Self-regulated learners will

> want to take increased responsibility for their own learning; be willing and capable of learning from and with others; participate in diagnosing, prescribing, and evaluating their own progress; clarify their values and establish goals consistent with their values; develop individual and group plans for achieving their goals; exercise self-discipline; understand their own learning style and be willing to try other potential useful learning styles; become familiar with and know how to use a variety of resources for learning; become capable of reporting what they have learned in a variety of ways; know when and where to ask for help or direction from others; analyze the dynamics of groups and become capable of using group decision-making process. (Della-Dora & Blanchard, 1979, p. 4)

They also

> know how to make effective plans before engaging in a task, they know how to monitor their own performance, and they know how to review and correct their work. They understand task-specific rules and generalizable heuristics. They know when to transfer strategies and when to seek help. The cognitive and metacognitive skills that they posses enable them to master new and challenging tasks in school. At the same time, these students have positive perceptions of their own competence. They see themselves as agents of their own learning who have control over the choice of strategies and volition to achieve their intended goals. They are optimistic learners in the goals they set and in their attributions of success to their efforts and investment of energy in appropriate tactics. They are task-involved and derive a sense of satisfaction and pride from their own efforts and mastery judged against their personal standards rather than social comparison. Self-regulation is thus enabling and empowering for continued learning." (Paris & Byrnes, 1989, p. 192-3)

Some contend that learner empowerment, coupled with academic expertise, fosters achievement (Paris & Byrnes, 1989). It may be argued that it is true or not true that "there is convincing evidence that people who take the initiative in learning (proactive) learn more things, and learn better, than do people who sit at the feet of teachers passively waiting to be taught (reactive learners)" (Knowles, 1975, p. 14). Certainly those who believe in self-directed learning believe that it has a positive effect on the quality of learning.

In the short quote above, Knowles sees a difference in emphasis on learning over teaching. Other supporters of self-directed learning also see a difference. Some claim that teaching interferes with the process of learning (Candy, 1991). "Many educationists have begun to recognize that teacher-controlled instruction is unwieldy, undemocratic, and unsound as a way of conducting education" (Candy, 1991, p. 205). When learners have little or no direction over their own learning, they are left to simply follow directions from others. Consequently, they come to depend on others' ideas instead of their own (Dirkes, 1993). In a teacher-directed learning environment, there is the erroneous assumption that the learner is essentially a "dependent personality" (Knowles, 1975). Self-directed learning is seen as a choice of "independent thinking over an inordinate dependence on *what I have been told*" (Dirkes, 1993, p. 20).

What aspects of learning could be controlled or directed by teachers or learners? Knowles identifies seven processes: climate setting; planning; diagnosing needs for learning; setting goals; designing a learning plan; engaging in learning activities; and evaluating learning outcomes (Knowles, 1975). For any one of these processes, is the teacher or the learner in control? Knowles does not answer this question directly, but does indicate, for example, that under self-directed learning, diagnosis of needs is done by "mutual assessment"; he seems to imply some give and take. This means that an increase in control by one is accompanied by a decrease in control by the other. It follows that the amount of teacher direction or control and learner control in any learning situation can be viewed on a single continuum. There is complete teacher control at one end, and complete learner control at the other; where as one moves towards learner control there is a "deliberate surrendering of certain prerogatives by the teacher accompanied by a concomitant acceptance of responsibility by the learner" (Candy, 1991, p. 9). To help illustrate the movement on such a scale, Candy placed various instructional strategies on this continuum. This is illustrated in the following figure 2-1.

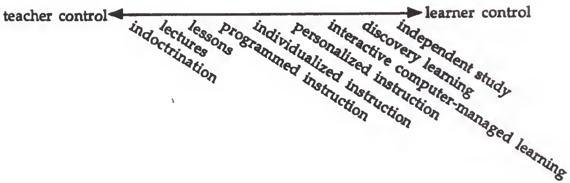

Figure 2 - 1. Candy's Teacher Control Learner Control Continuum

Candy goes on to apply this teacher control / learner control continuum to another domain, the autodidactic domain, which he states overlaps the instructional domain (Candy, 1991).

Is self-directed learning itself a characteristic? Some believe, or at least assume, that "self-direction" in learning is best viewed as a continuum or characteristic that exists to some degree in every person and learning situation (Husén & Postlethwaite, 1994; Guglielmino, 1977). Guglielmino states that "it is the personal characteristics of the learner -- including his attitudes, his values, and his abilities -- which ultimately determine whether self-directed learning will take place in a given learning situation" (1977, p. 34). We could ask, "what are the characteristics that identify a self-directed learner?" Candy states that self-directed individuals are "people who exhibit the qualities of moral, emotional, and intellectual autonomy" (1991, p. 19) Paris and Byrnes assert that self-regulated learners possess a "combination of positive expectations, motivation, and diverse strategies for problem solving" (1989, p. 169). This raises the question, "is there a comprehensive list of learner characteristics that are needed, or should be enhanced, to increase someone's capacity or readiness for self-directed learning?" From a review of 20 sets of authors, Candy develops the following list: be methodical and disciplined; be logical and analytical; be reflective and self-aware; demonstrate curiosity, openness and motivation; be flexible; be interdependent and interpersonally competent; be persistent and responsible; be venturesome and creative; show confidence and have a positive self-concept; be independent and self-sufficient; have developed information-seeking and retrieval skills; have knowledge about, and skill at, learning generally; develop and use defensible criteria for evaluating learning (Candy, 1991, p. 130). Guglielmino uses a Delphi survey of experts in the field to produce the following list, ordered by a measure of desirability from high to low as designated by the survey: initiative; independence; persistence; sense of responsibility for one's own learning; tendency to view problems as challenges; self-discipline; high degree of curiosity; strong desire to learn or change; ability to use basic study skills; ability to organize one's time and set an appropriate pace for learning; self-confidence; ability to develop a plan for completing work; joy in learning; tendency to be goal oriented; tolerance of ambiguity; preference for active participation in shaping educational program; ability to evaluate own progress; intellectual responsibility; patience; ability to diagnose own learning needs; exploratory view of education; above average risk-taking behavior; knowledge of a variety of potential learning resources and ability to use them;

ability to accept and use criticism; ability to discover new approaches for dealing with problems; ability to formulate learning objectives; tendency to be task oriented; ability to select and use many learning strategies; positive orientation to the future; emotional security; average or above average intelligence; creativity; preference for independent study or relatively unstructured courses (Guglielmino, 1977, p. 55 - 56).

Grow states that "readiness" is a combination of ability and motivation (1991). The lists above certainly reflect this notion. The notion that motivation, as well as ability, is an important ingredient in readiness for learning, is not new. Dewey, in his famous book How We Think, claims that "open-mindedness," "whole-hearted or absorbed interest" and "intellectual responsibility" are "essential constituents" of a general readiness for learning (1933, p. 30 - 34). But does a readiness for self-directed learning equate to a general readiness for learning? Critics of Guglielmino's Self-Directed Learning Readiness Scale argue that it measures a general readiness or love for learning in that those items that had the highest correlations were related to a general love of learning, not to self-direction in learning. Guglielmino counters that several of the items that have high correlations, including the third highest, were related strongly to self-direction in learning (Guglielmino, 1989). Knowles states that there is a significant difference between teacher-directed and self-directed learning in the development of readiness to learn; teacher-directed learning assumes that readiness to learn "varies with levels of maturity," whereas self-directed learning "develops from life-tasks and problems" (1975, p. 60). Obviously some people believe that there is a general readiness for learning and readiness for self-directed learning.

What motivates a learner to be self-directed? One general motivational factor is the basic need for self-respect and self-esteem (Della-Dora & Blanchard, 1979; Guglielmino, 1977; Knowles, 1975). Knowles addresses the motivational differences between teacher-directed learning, which "assumes that the learner is motivated to learn in response to external rewards and punishments, such as grades, diplomas, awards, degrees, and fear of failure," and self-directed learning which "assumes that the learner is motivated by internal incentives, such as need for esteem (especially self-esteem), the desire to achieve, the urge to grow, the satisfaction of accomplishment, the need to know something specific, and curiosity" (Knowles, 1975, p. 21). The motivation for a self-directed learner is different than for an other-directed learner. Dirkes states that in a teacher directed environment, satisfying an instructor becomes more important than learning (1993).

There are several factors that affect motivation with regard to self-directed learning. Dirkes gives three of them: degrees of challenge, curiosity, and control (Dirkes, 1993). Students can be motivated by a challenge as long as the challenge is not too low or too high (Dirkes, 1993). Challenge and curiosity are related in that a person's interest or curiosity is often increased when given a challenging situation. This is not to say that children are interested in every reasonable challenge: children are often interested in computer and video games that are just as challenging, if not more so, than many classroom activities which they find uninteresting. Why the difference? Dirkes posits that in a computer game "the uncertainty of the challenge breeds curiosity. The more uncertainty the more curiosity, especially when the responsibility for reducing uncertainty rests with the person engaged in the game. The correlation changes, however, for academic encounters considered outside a student's responsibility for reducing uncertainty. Here students often correlate uncertainty with difficulty. If students favor immediate success over challenge, curiosity and imagination diminish accordingly" (Dirkes, 1993, p. 23). This would imply that curiosity itself can be affected by the level of individual control. Candy states that research done in the 1960s indicates that "as people were given, and accepted, increased responsibility for valued instructional functions, there was a concomitant rise in their curiosity and information-seeking behavior (Candy, 1991, p. 56).

Students' beliefs about their own characteristics as related to learning competence affect their motivation. One of those characteristics is personal agency, which refers to the belief that "people take responsibility for their actions and ascribe success and failure to the goals they choose, the resources they mobilize, and the effort they expend" (Paris & Byrnes, 1989, p. 176). Factors promoting personal beliefs in agency are success in task mastery, observation of the behavior of others that they believe they can emulate, and social persuasion. Self-efficacy is an important component of agency, and children who have high self-efficacy choose challenging tasks and persist in the face of failure (Schunk 1986).

Another attribute relevant to students' perceptions of their own competence is control. Control beliefs refer to the "expectations that individuals hold about the likelihood that they can attain desired outcomes" (Paris & Byrnes, 1989, p. 177). With respect to self-directed learning, this means a belief in the opportunity and ability to make decisions concerning the goals and management of learning. This sense of control does not mean a sense of "power over others" (Garrison, 1992, p. 143). In fact, control must be realized through collaboration of the learner and a facilitator of learning (i.e.

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teacher) (Garrison, 1992). As stated earlier, goal-setting is one task of a self-directed learner. Individuals will set and pursue goals only if they have strong beliefs that they can control their actions to obtain their goals (Paris & Byrnes, 1989). In general, learners' willingness to accept responsibility for their own learning is very much dependent on the belief of having some control of the learning process (Garrison, 1992)

Della-Dora and Paris' lists of what self-directed learners do imply that a certain academic ability level is needed for self-directed learning. Also important is what students believe about their own ability (Candy, 1991; Paris & Byrnes, 1989). According to Dirkes, "when students trust their own reading and thinking, understanding becomes a driving force" (Dirkes, 1993, p. 37). Nichols states that research has shown that children's perceptions of their academic abilities are significantly higher in the early years of schooling than in the latter years (Nichols, 1984). Does this decline correlate to the general reliance on other-directed learning as opposed to self-directed learning? Blumenfeld asserts that by the fifth and sixth grades, "social comparisons" and "external evaluations" (i.e. grades) gradually become the primary basis for self-perceived competence (Blumenfeld, 1989). This decline in self-perceived competence contributes to a greater reliance on others. For example, Dirkes explains that many students are influenced by a belief that they are "not good at math or that they know math but do not perform well," and consequently they simply "catch bits of information and rely upon teachers to put it together" (Dirkes, 1993, p. 1). He goes on to state that "students don't know what they can do. Only their own direction will show them" (Dirkes, 1993, p. 4).

Students' beliefs in agency, control, and ability certainly affect the amount of effort they are willing to expend in a learning endeavor. Many students attribute success to ability and tend to ignore the importance of effort as a cause of success and failure (Bar-Tal, 1978). Young children up to the age of 7 or 8 believe that intelligence can be positively affected by effort, but by age 12 they believe that they have a fixed amount of intelligence that is unaffected by effort and results in feelings that "trying hard is perceived as a sign of low ability" whereas "success with high effort is less valued than effortless success" and "effort with failure is a devastating sign of poor ability" (J.G. Nichols, 1978, p. 186). This affects problem solving in that many students "are prone to answer quickly or abandon problems without attempting to find answers. Rather than rely on their own ability to figure things out, these students want certainty before they proceed" (Dirkes, 1993, p. 5).

Some see self-directed learning as beneficial, if not necessary, for success in problem-solving and critical thinking. "To be a critical thinker, one needs to be self-directed; and conversely, to be a self-directed learner, one needs to be a critical thinker" (Garrison, 1992, p. 145). Paul suggests further that critical thinking can be defined as "disciplined self-directed thinking" (Garrison, 1992, p. 145). In either case, good critical thinking is seen as a prerequisite for and an outcome of self-directed learning. Candy contends that "prolonged and consistent exposure to learner-control seems to lead to collateral gains in curiosity and critical thinking" (Candy, 1991, p. 242). Garrisons states that critical thinking is "not a generalized ability or skill. It is a process of making sense (internal cognitive process) of external processes through analysis of issues and information" (Garrison, 1992, p. 138). He indicates that even though the need for critical thinking in a given situation is precipitated by an outside source, it is the "responsibility of the individual to make sense of the situation by integrating new ideas with previous knowledge and experience" (Garrison, 1992, p. 139). One aspect of making sense is sorting out essential from non-essential information. When this is the responsibility of the leaner, "quality and retention of understanding seem to be enhanced" (Candy, 1991, p. 242). Another aspect is the notion of reducing dissonance between any new information and/or experience with internalized cognitive structures. This need to reduce dissonance "demands a proactive form of thinking and acceptance of responsibility for interpreting " the new information and/or experience (Garrison, 1992, p. 138).

Problem-solving is often seen as an important part of the learning of mathematics. It is even promoted as the "underlying theme in the mathematics classroom" (Milauskas, 1987, p. 69). related to critical thinking and is therefore related to self-directed learning. According to Knowles, "teacher-directed learning assumes that students see learning . . . as accumulating subject matter . . . whereas self-directed learning assumes that [students'] natural orientation is task or problem centered learning" (Knowles, 1975, p. 20). Students who view learning as "accumulating subject matter" depend on having learned from someone else the necessary strategy for solving a particular problem and in the end become dependent "on quick recall as routine strategy. They rarely ask questions, elaborate on ideas, or use spatial representations. The most common response to a challenge is a brief answer or the abandonment of problems" (Dirkes, 1993, p. 3). Students tend to believe that they are supposed to know what to do immediately when facing a problem or task. The focus of an academic task often becomes "task completion rather than thoughtful engagement," and the view that a task is basically "work-to-be-accomplished circumvents rather than promotes learning" (Paris & Byrnes, 1989, p. 180) A self-directed problem-solver does start with "routine strategies" but realizes when they are inadequate and generates new ideas that form the basis for new strategies and solutions that they have never seen (Dirkes, 1993). This notion of idea production is central to Dirkes' vision of self-directed problem solving. "The notion of problem solving expands when students see themselves as idea producers for any situation that poses a dilemma, whether the uncertainty appears in words, symbols, drawings or people" (Dirkes, 1993, p. 63). He adds that students' understanding of the nature of problem solving can be enhanced by: "(a) encountering novel types of problems continuously, (b) encouragement to seek comprehension over efficiency, (c) freedom from an urgent need to get external reinforcement, and (d) dialogical interaction. Under these conditions, problem solvers are willing to think without having a clear direction. They develop much more confidence and self-direction than those who depend largely on routine thinking" (Dirkes, 1993, p. 63).

It is important to remember that self-directed learning does not imply that learning takes place in a completely autonomous environment. (Garrison, 1992; Guglielmino, 1977; Husén & Postlethwaite, 1994; Knowles, 1975) "The learner is neither independent or dependent -- the learner is interdependent with facilitators and fellow learners. The nature of this interdependence is what we need to understand and the fact that the balance of interdependence will dynamically shift from one circumstance to another" (Garrison, 1992, p. 144). In a typical public school setting, the term facilitators refers to teachers and their primary role as facilitators of learning. The list of tasks or responsibilities of a facilitator would include intellectual dialogue with learners, securing resources, evaluating outcomes, and promoting critical thinking, (Husén & Postlethwaite, 1994) as well as asking students to "look for alternatives and design new ways to use their abilities and opportunities along with many traditional approaches to learning and problem solving" (Dirkes, 1993, p. 20). As a general rule, teachers do not do anything that students can do for themselves (Dirkes, 1993). Garrison points out that there is no contradiction between a self-directed learner who assumes responsibility for learning with a reliance on a facilitator (Garrison, 1992). It is also the role of the facilitator to help develop and encourage the ability and desire of a learner to be a self-directed learner (Garrison, 1992).

Self-Directed Learning Readiness Scale

Description

The Self-Directed Learning Readiness Scale (SDLRS) is a widely used measurement of an individuals' readiness for self-directed learning. It has been the subject of various validation studies (Field, 1989; Long & Agyekum, 1983; Long & Agyekum, 1984; Mourad & Torrance, 1978), and has been used as an instrument in many studies, including according to one source, "more than 20 doctoral studies" (Field, 1989, p. 125) and more recently "more than 50 doctoral studies" (P. J. Guglielmino, personal communication, January 24, 1995). General discussions of its development and use can also be found (Bonham, 1991; Brockett, 1985a; Field, 1990; McCune, 1989). Though most of the literature regarding the SDLRS is found in the field of adult or continuing education, learners covering a wide range of ages have been used. It has been administered to gifted students from grades 5 through 12 (Mourad & Torrance, 1978), high school students (Guglielmino, 1977), college students (Caffarella & Caffarella, 1986; Field, 1989; Guglielmino, 1977; Long & Agyekum 1983), and senior citizens (Brockett, 1985b). Overall, the SDLRS has been used by "more than 500 major organizations," given to "more than 40,000 adults and 5,000 children," and translated into nine other languages (P. J. Guglielmino, personal communication, January 24, 1995).

In its present form, the scale consists of 58 statements of learning preferences and attitude towards learning as described by the instructions to the user. Each item incorporates a five-point Likert scale. Both positive statements ("I love to learn") and negative statements ("I'll be glad when I'm finished learning) are included. The user is asked to give one of five possible responses to each statement. The possible responses range from "Almost never true of me; I hardly ever feel this way" at one end of the scale, to "Almost always true of me; there are very few times when I don't feel this way" on the other. Each response is given a score from one to five and a total score is derived from summing the score of each item. A higher score is indicative of a greater readiness for self-directed learning.

Development

The Self-Directed Learning Readiness Scale was developed by Dr. Lucy Guglielmino in 1977. It was the focus of her dissertation study while at the University of Georgia. The study consisted of two major parts. The first was to identify the major characteristics of a self-directed learner. Based on the Delphi technique, three rounds of questionnaires were sent to a "panel of experts" who were chosen "on the basis of frequently cited publications in the area of self-direction [in learning] or quality of recent research" (Guglielmino, 1977, p. 32). Out of the 20 experts who were asked, 13 completed all three sets of questionnaires, 14 completing the first two.

The first questionnaire asked each expert to list "at least 10 of the most important personality characteristics of self-directed learners, preferably those amenable to measurement" (Guglielmino, 1977, p. 33). After creating their lists, they were asked to read a list of characteristics that Guglielmino attested were "suggested by the literature" and to add any of those to their list or to highlight the ones already in their list. In the instructions for the questionnaire, Guglielmino provided the following statement to describe her assumptions with regard to self-directed learners:

> It is the author's assumption that self-direction in learning exists on a continuum; it is present in each person to some degree. In addition, it is assumed that self-direction in learning can occur in a wide variety of situations, ranging from a teacher-directed classroom to self-planned and self-conducted learning projects. Although certain learning situations are more conducive to self-direction in learning than others, it is the personal characteristics of the learner -- including his attitudes, his values, and his abilities -- which ultimately determine whether self-directed learning will take place in a given learning situation. The self-directed learner more often chooses or influences the learning objectives, activities, resources, priorities, and levels of energy expenditure than does the other-directed learner. (Guglielmino, 1977, p. 34)

The characteristics from the first questionnaire were compiled and edited to form a second questionnaire with 52 characteristics. Included in the second questionnaire were items such as "independence", "self-confidence", "high degree of curiosity", "above average risk taking behavior", "knowledge of a variety of potential learning resources and ability to use them" as well as the to be expected "average or above average intelligence", "previous training in field of study", "high reading level" and "ability to use basic study skills" (Guglielmino, 1977, p. 99). In the second questionnaire, the experts were asked to rate each characteristic as unnecessary, desirable, necessary, or essential as defined by the author. A seven-point scale, with half point increments where 1 = unnecessary and 7 = essential, was used. Four additional characteristics were added as the experts were also "encouraged to add and rate any characteristic which they felt should be added to the list" (Guglielmino, 1977, p. 35). In the third questionnaire, the same characteristics were listed along with marks indicating the 25th, 50th and 75th percentile rankings of each characteristic. The panel was asked to rate each characteristic again using the same point scale and to "give reasons to justify their response" for ranking any item "outside the middle 50% of the responses of the group" (Guglielmino, 1977, p. 35 - 36).

The final ranking had 30 items ranked between desirable and necessary and three items between necessary and essential. These 33 characteristics served as a basis for constructing the 41 scale items that were constructed. As stated by the author, a

> . . . one-to-one correspondence between SDLRS items and characteristics selected by the Delphi survey was not possible, since situational and attitudinal items were desired. One item often involved more than one characteristic. An attempt was made to represent the characteristics which were rated the highest in the Delphi survey by more than item. (Guglielmino, 1977, p. 38)

The items were reviewed for appropriateness in regard to the "principle of measurement" and grammar and semantics (Guglielmino, 1977). This resulted in five items being revised. A pre-tryout with 10 persons was used to finalize the instructions for the scale.

Using cluster-sampling, the scale was given to 307 students. Forty-two were Georgia public high school juniors and seniors in a marriage and family course, 53 were Canadian high school seniors in an English course, 180 were undergraduate college students enrolled in 12 different day and night classes in various subjects (educational psychology, chemistry, accounting, literature, history, mathematics, political science, psychology and sociology), and 32 students in non-credit continuing education courses. Of the 307 responses, 304 were deemed to be "usable." The highest possible score obtained from the scale was 205.

Statistical analysis included mean (148.96), standard deviation (18.46), range (129: 60 - 189), estimated reliability (Cronbach-Alpha coefficient = .87), product-moment correlations between each item and the total score (-.01 - .54), and item difficulty (50% - 93%). A cutoff value for item difficulty of .81, for item correlation of .30, and the "importance of the concept measured," were set as selection criteria for the item revision. A principal components factor analysis revealed thirteen factors initially, trimmed down to eight factors after the Kaiser-Guttman rule was applied. Two-factor and five-factor solutions were also tried, but the eight-factor solution was deemed to be "the most meaningful and interpretable solution" (Guglielmino, 1977, p. 60).

Each factor was the interpreted and named and the items that loaded on each factor were identified. The items in the scale were reviewed for revision. Seven were made more difficult and ten items were revised "in order to increase their correlation with the test as a whole" (Guglielmino, 1977, p. 69). No testing of the revised scale was conducted in this study.

> In that an effort was made to increase the difficulty of seven items, and to increase the homogeneity of 10 other items, the mean of the revised scale will probably be lower and the standard deviation and reliability greater than the estimate based on the item analysis data from the tryout version. (Guglielmino, 1977, p. 69 - 70)

Later, the wording of two items were revised and 17 items were added to the scale to produce the current version of the scale. In a recent study by the author using the current version of the SDLRS and a sample of 3151 individuals, a "reliability estimate of the SDLRS, based on a split-half product moment correlation with Spearman-Brown correction" of .91 was found (Guglielmino, 1991, p. 24). In addition to the current version for the "general adult population", there is a self-scoring form which uses the same 58 items and scoring procedure but a slightly different form to record the responses

(Guglielmino & Guglielmino, 1995). Also, there are forms for "adults with low reading levels or non-native English speakers" and a form for elementary children (Guglielmino & Guglielmino, 1995). Dr. Paul Guglielmino advised that 10th graders use the adult form unless they "have a very low reading level in which case they should use the [children's] form" (P. J. Guglielmino, personal communication, January 24, 1995).

Support and Criticism

Several studies have been undertaken to establish or confirm the validity and reliability of the SDLRS. From a sample of 3151 individuals a "reliability estimate of the SDLRS, based on a split-half product moment correlation with Spearman-Brown correction" of .91 was found (Guglielmino, 1991, p. 24). Other studies cited in the literature as showing support for the validity of the SDLRS include Long and Agyekum, (1983, 1984), Mourad and Torrance (1978, 1979), Brockett (1985a), Carney (1985/86), Hassan (1981), Finestone (1984/86), and Sabbaghian (1979) (Hassan, 1981; Long & Agyekum, 1983; Long, 1989; Mourad & Torrance, 1978; Brockett, 1985a). Though Field stated that few studies have been undertaken to validate the SDLRS and that "the most thoughtful of these have been primarily qualitative and conceptual, " Long countered that Field has ignored a study by Finestone, three studies by Torrance and Mourad, and a study by Carney that lend support for the validity of the SDLRS (Field, 1989; Long, 1989). One method for validating the SDLRS was to find a significant relationship or correlation between the SDLRS and other constructs. A discussion of these studies and related discussion follow in the next section.

One area of discussion of the validity of the SDLRS concerned whether the scale actually measures what its supporters say it does. Field criticized

Guglielmino for not giving a definition for self-directed learner in her original development of the scale. He contends that this makes for a very unsound conceptual framework (Field, 1989). Guglielmino responded by claiming that even though she did not define "self-directed" learner, it was defined by the "Delphi panel" (Guglielmino, 1989). In addition, Long states that Guglielmino's "dissertation was designed to contribute to the development of definitions" and that the use of a "firm definition in her communications with her panel [of experts] would have been a limiting factor (Long, 1989). Field also states that Guglielmino's use of the Delphi technique was an inappropriate method "of generating items which are required to depict the various components of readiness for self-directed learning" (Field, 1989). Guglielmino counters that the Delphi technique was only used to obtain a list of "the characteristics of the self-directed learner" that served as basis for the items themselves (Guglielmino, 1989).

Field in citing studies that he claimed show no significant or low correlation between SDLRS scores and other constructs, contends that the majority of studies using the SDLRS have been "vague in assessing what the SDLRS measures" (Field, 1989). He concludes that the SDLRS "does appear to be related to love and enthusiasm for learning" (Field, 1989). He supports this by stating that the items which had the highest correlations were related to a general love of learning, not self-direction in learning (Field, 1989). Bonham (1991) also contends that the wording of the questions, especially the reverse scored items, suggests that low scores indicate a "dislike for learning in general" and therefore high scores would reflect a "positive attitude towards learning, regardless of the amount of control that the learner has over planning that learner" (Bonham, 1991). Guglielmino counters that several of the items that had high correlations, including the third highest, were related strongly to self-direction in learning (Guglielmino, 1989).

The wording of some of the scale items, especially the use of negative wording or reverse items such as "constant learning is a bore," has been debated. Field states that according to the scale, "readiness for self-directed learning corresponds to agreement with a positive item and disagreement with a negative item." He contends that in the SDLRS, "a number of flaws . . . exist in item wording and in item/response-option combinations." He gives a few examples of "dual phrasing of response items", "the generality of some items" and the "ambiguity of the term 'learning'" (Field, 1989, p. 130). Guglielmino gives examples where high self-direction is indicated by a positive response to negatively-phrased items and by a negative response to positively-phrased items. She states that the use of reverse items was needed to help guard against the user developing a response set (Guglielmino , 1989). Field found that the correlations between individual items and the overall score were significantly lower for negatively-phrased items than for positively-phrased items and therefore the negatively phrased items were a "serious source of invalidity" (Field, 1989). McCune criticized the statistics method Field used to determine this and Field later acknowledged the error (McCune, 1989; Field, 1990).

In another discussion dealing with the correlations between individual items and the overall score, Brockett reported that 12 of the 58 items were not significantly correlated ($p < .05$) with the total score (Brockett, 1985a). Field also reported in his study that 12 items did not meet the minimum requirement he set of $r = .30$. Guglielmino stated that Field's results were a result of a sample that was too small (244) and homogeneous (vocational education teachers and students in adult education). Citing an unpublished study she did with 3,151 respondents, only one item had a correlation less than .30 (Guglielmino, 1989).

Another area of discussion centered on the eight factors Guglielmino reported in her original work. Mourad and Torrance performed a factor analysis in their 1978 study of gifted students and also found eight factors, though not identical to Guglielmino's. However, they stated that several of their factors corresponded to Guglielmino's and concluded that any discrepancy was not due to a "deficit of the scale, [but] of the analysis procedure and samples used. Data structures are always different from sample to sample." (Mourad & Torrance, 1978) Field cited a study conducted in 1989 by West and Bentley that concluded that the eight-factor model is "clearly inadequate" and that the one factor model provided a better fit. It was concluded that the overall score would provide a better score than the "highly interrelated factor scores" (Field, 1990). Field's own factor analysis failed to show support for the same eight factors cited by Guglielmino and he concluded that the SDLRS measures a homogeneous construct (Field, 1989). McCune states that Field incorrectly used a different procedure than Guglielmino and therefore different factors should have been expected (McCune, 1989).

Dynamic Geometry Computer Software and the Constructivist Approach to Learning Mathematics

According to Davis et al. (1990), hypothesizing, trying things out, executing mathematical procedures, communicating and defending results, and reflecting on the methods used and conclusions reached are, from a constructivist perspective, the activities that are "part of what it means to engage in mathematics. Learning mathematics requires construction, not passive reception, and to know mathematics requires constructive work with mathematical objects in a mathematical community" (Davis et al., 1990, p. 2). For the sake of this discussion, constructivism will be described by Goldin's summary of the themes found in constructivist views of learning mathematics. The pertinent ones are:

> (1) a view of mathematics as *invented* or *constructed* by human beings, rather than an independent body of truths or an abstract and necessary set of rules; (2) an interpretation of mathematical meaning as *constructed by the learner* rather than imparted by the teacher; (3) a view of mathematical learning as occurring most effectively through *guided discovery, meaningful application,* and *problem solving,* as opposed to imitation and reliance on the rote use of algorithms for manipulating formal symbols; (4) the study and assessment of learning through individual interviews and small-group case studies, which go far beyond traditional pencil-and-paper tests; (5) approaches to effective learning through the creation of classroom learning environments, encouraging the development of diverse and creative problem-solving processes in students, and reducing the exclusive emphasis on mathematically correct responses. (Goldin, 1990, p. 31)

Constructivism is based on the notion that individuals construct their own knowledge. Who is responsible for that construction? Von Glaserfeld states that in a sense, "it is we who are responsible for the world we are experiencing" and it "does not seem untimely to suggest a theory of knowing that draws attention to the knower's responsibility for what the Knower constructs" (Von Glaserfeld, 1990, p. 28). This concurs with the notion that learners have or should have significant responsibility for managing their own learning. Confrey goes so far as to claim that "personal autonomy is the backbone of the process of construction" (Confrey, 1990, p. 111).

How does this relate to the various tools that students might use in a learning situation? Dynamic geometry software such as The Geometer's Sketchpad is often described as "tools to think with." The purpose of "tools to think with" is to make it "entirely possible for the children to carry out their own analyses of problems, and to invent their own methods of solution" (Davis, 1990, p. 97). Computer software tools with their extensive graphics and interactive abilities, are "qualitatively new" (Balacheff, Bell, Bishop, Cooney, Dörfler, Hoyles, Jones, Movshovitz-Hadar, Romberg, & Zehavi, 1990). The possibilities of such software include "the synchronous representation of different but related processes and situations" (Balacheff et al., 1990, p. 145) and geometric constructions that can be generated quickly and then "dynamically manipulated to develop students' intuitive understanding of geometry" (Computing Teacher, 1992, p. 49).

Inquiry is certainly an important aspect of constructivism. One important cognitive tool incorporates the manipulation of objects. From a constructivist viewpoint, students must be allowed to manipulate objects in a truly exploratory manner. They must also have their own purposes for manipulating objects (Noddings, 1990). It may be necessary initially to provide some direct instruction on the use of various manipulatives to prevent them from being "as mysterious as numerals" to students. But after that, Noddings recommends simply making available the opportunity to manipulate the objects. "In actual problem-solving situations, we probably should not guide students in their use. If we do, we are likely to detach students from their own purposes and set them blindly to work on our own . . . we want their constructions to be guided by mathematical purposes, not by the need to figure out what teachers want or where they are headed"

(Noddings, 1990, p. 16). Dynamic geometry software allows students to define for themselves why and how their constructions are to be manipulated.

The manipulation of constructions is beneficial in more ways than those that lead to searching for patterns, conjecturing and generalizations. Goldin speaks of a "verifiability criterion of meaning" which refers to the notion that "the only meaningful content of a synthetic statement consists of the methods whereby it can in principle be confirmed or disconfirmed observationally" (Goldin, 1990, p. 34). With dynamic geometry software, students can visually confirm or disconfirm their own conjectures instead of having to rely on mental manipulations or to simply accept them (Giamati, 1995).

The incorporation of constructivist views into an environment for the learning of geometry, or any mathematical subject for that matter, may conflict with students' default learning styles. Some students are "insecure with their own mathematical ability, and find reassurance in procedures and algorithms that can be implemented in a fairly mechanical but at least a reliable way" (Goldin, 1990, p. 46). Confrey states that in problem solving, directed guidance may help to lower a student's frustration level (Confrey, 1990). Hints may be needed (Milauskas, 1987). However a shift towards self-directed learning is the key for successive problem solving. But is that possible? In a recent study of high school students' use of The Geometer's Sketchpad, findings "suggests that learning styles can be influenced, and students can be encouraged to expand their problem solving strategies, regardless of prior knowledge or abilities" (Robinson, 1994, p. 99).

There have been some attempts to verify experimentally the benefits of using dynamic geometry software. A study of problem solving strategies used by high school geometry students showed no significant difference in performance on the Locus-Motion Inventory (LMI) between students who used The Geometer's Sketchpad and those who did not have access to computer software (Robinson, 1994). However, all the students had received instruction in the use of The Geometer's Sketchpad and the author reported that "the strategies employed with the computer carried over to the paper and pencil problems" (Robinson, 1994, p. 89). In a study of middle school students' construction of concepts of reflection and rotation, and on students' two and three dimensional visualization, students using The Geometer's Sketchpad outperformed students working in a traditional environment on every measure except three-dimensional visualization (Dixon, 1995).

Geometric Supposer is another known software for the study of geometry that, although not dynamic like The Geometer's Sketchpad, is designed to help students make and test conjectures. It has also been the focus of experimental studies. In a study comparing students who learned "geometry inductively" using the Geometric Supposer, with students who learned "traditional, deductive geometry", one of the conclusions Yerushalmy reached was that "the traditional geometry course reduced the motivation of students to think about richer ideas or to change what were assumed to be key features, while inductive learning helped students consider non-conventional methods of analysis" (Yerushalmy, 1986). An experimental design study compared the effect of periodic use of the "Geometric Supposers" software to non-use on geometry achievement of two tenth grade classes. McCoy concluded that the data indicated no difference in achievement on the lower level questions but the data did "suggest" that The Geometric Supposers promotes increased achievement on the higher level and application problems (McCoy, 1990 & 1991).

Also used are other types of graphical-oriented computer software in the study of geometry as well as other mathematical subject areas such as algebra. One type are micro-worlds which Edwards referred to as a "dynamic computer-based environment" (Edwards, 1989). In a study of 12 middle school students studying transformational geometry, she reported significant changes in the students' knowledge of the transformations. She also reported "qualitative changes in the students' knowledge [that] included a shift from viewing the transformations as combinations of local changes (e.g., in heading and location) to considering them as whole-plane operations," and changes in strategy in the use of graphical and the symbolic representations of the transformations; "in many cases, the students' goals evolved from simply satisfying the demands of the task to pursuing original investigations in the microworld" (Edwards, 1989). In a study of college algebra students and a "highly visual" computer enhanced instruction, Kiser (1990) found a significant interaction between spatial ability and a "highly visual" computer enhanced instruction (Kiser, 1990; Dixon, 1995).

Summary

The review of literature presented in this chapter started with a theoretical framework for self-directed learning. An increased educational emphasis on students taking a more active role in directing their own learning was sketched. A measurement of an individuals' readiness for self-directed learning was determined to be beneficial in assessing the ability and desire of a student to direct their own learning and the extent to which that readiness can be affected. The review of the development and use of the Self-Directed Learning Readiness Scale (SDLRS) revealed that it has been considerably discussed, tested and used. The incorporation of dynamic geometry computer software in the environment for the study of geometry was also outlined in this chapter. This section included a focus on constructivism as a link between self-directed learning and the use of dynamic geometry computer software. This review showed extensive interest in these main areas and indicates a need for study of how these areas are related to each other.

CHAPTER 3
METHODOLOGY

This study examined the influence of problem-solving activities using dynamic geometry computer software on an individual's readiness for self-directed learning. Other factors influencing an individual's readiness for self-directed learning, attitude towards mathematics and computers, were also studied.

Research Questions

The research questions that were addressed by this study are listed below. Following each question is the list of hypotheses pertaining to that question that were statistically tested.

1. Will doing problem-solving activities using dynamic geometry computer software (i.e. the Geometer's Sketchpad) make a difference in a student's readiness for self-directed learning?

   Hypothesis: There is no significant difference in the change in Self-Directed Learning Readiness Scale (SDLRS) scores between students grouped by experimental treatment.

   Hypothesis: There is no significant difference in the change in Self-Directed Learning Readiness Scale (SDLRS) scores between students grouped by teacher.

Hypothesis: There is no significant difference in the change in Self-Directed Learning Readiness Scale (SDLRS) scores between students grouped by class period.

Hypothesis: There is no significant difference in the change in Self-Directed Learning Readiness Scale (SDLRS) scores between students grouped by grade.

Hypothesis: There is no significant difference in the change in Self-Directed Learning Readiness Scale (SDLRS) scores between students grouped by gender.

2. Will doing problem-solving activities using dynamic geometry computer software (i.e. the Geometer's Sketchpad) make a difference in a student's performance in geometry?

   Hypothesis: There is no significant difference in students' grade in geometry for the fourth quarter between students grouped by experimental treatment.

   Hypothesis: There is no significant difference in students' grade in geometry on the second semester final exam between students grouped by experimental treatment.

3. Will doing problem-solving activities using dynamic geometry computer software (i.e. the Geometer's Sketchpad) make a difference in a student's attitude towards mathematics?

   Hypothesis: There is no significant difference in the change in Fennema-Sherman Mathematics Attitudes Scales scores between students grouped by experimental treatment.

   Hypothesis: There is no significant difference in the change in Fennema-Sherman Mathematics Attitudes Scales scores between students grouped by teacher.

Hypothesis: There is no significant difference in the change in Fennema-Sherman Mathematics Attitudes Scales scores between students grouped by class period.

Hypothesis: There is no significant difference in the change in Fennema-Sherman Mathematics Attitudes Scales scores between students grouped by grade.

Hypothesis: There is no significant difference in the change in Fennema-Sherman Mathematics Attitudes Scales scores between students grouped by gender.

4. Will doing problem-solving activities using dynamic geometry computer software (i.e. the Geometer's Sketchpad) make a difference in a student's attitude towards computers?

   Hypothesis: There is no significant difference in the change in Computer Attitude Scale scores between students grouped by experimental treatment, teacher, class period, grade or gender.

   Hypothesis: There is no significant difference in the change in Computer Attitude Scale scores between students grouped by teacher.

   Hypothesis: There is no significant difference in the change in Computer Attitude Scale scores between students grouped by class period.

   Hypothesis: There is no significant difference in the change in Computer Attitude Scale scores between students grouped by grade.

   Hypothesis: There is no significant difference in the change in Computer Attitude Scale scores between students grouped by gender.

5. How are experience with computer-based mathematics tools, attitude towards mathematics and the learning of mathematics, attitude towards computers and using computers, and an individual's readiness for self-directed learning and mathematics achievement related to each other?

Hypothesis: There is no significant difference in the change in SDLRS scores between students grouped by experimental treatment due to interaction effect of experimental treatment and attitude towards mathematics and attitude towards computers.

Hypothesis: There is no significant difference in the change in SDLRS scores between students grouped by experimental treatment due to interaction effect of experimental treatment and achievement in geometry.

Hypothesis: There is no significant change in SDLRS scores due to interaction effect of experimental treatment and attitude towards mathematics and attitude towards the Geometer's Sketchpad.

Hypothesis: There is no significant change in SDLRS scores due to interaction effect of attitude towards computers and attitude towards the Geometer's Sketchpad.

Instruments

Three attitude instruments which have been used in other studies and have been statistically validated were used in this study. They were the Self-Directed Learning Readiness Scale (SDLRS), Computer Attitude Scale (CAS) and the Fennema-Sherman Mathematics Attitudes Scales.

The Self-Directed Learning Readiness Scale (SDLRS) is a widely used measurement of an individual's readiness for self-directed learning. It has been the subject of various validation studies (Field, 1989; Long & Agyekum, 1983; Long & Agyekum, 1984; Mourad & Torrance, 1978). In one recent study using a sample of 3,151 individuals, a "reliability estimate of the SDLRS, based on a split-half product moment correlation with Spearman-Brown correlation" of .91 was found (Guglielmino, 1991, p. 24). The scale consists of

58 statements of learning preferences and attitude towards learning as described by the instructions to the user. Each item incorporated a five-point Likert scale. Both positive statements ("I love to learn") and negative statements ("I'll be glad when I'm finished learning") are included. The user is asked to give one of five possible responses to each statement. The possible responses range from "Almost never true of me; I hardly ever feel this way" at one end of the scale to "Almost always true of me; there are very few times when I don't feel this way" on the other end. Each response is given a score from 1 to 5 and a total score is derived by summing the score of each item. A higher score is indicative of a greater readiness for self-directed learning.

The Computer Attitude Scale (CAS) is designed to measure attitude toward computers and their use. The scale includes three subscales: computer anxiety, computer confidence, and computer liking. In a study of 155 students in grades 8 - 12, an overall reliability score of .95 (Cronbach alpha) along with scores of .86, .91, and .91 for anxiety, confidence, and liking were obtained (Loyd & Gressard, 1984). The CAS consists of 29 statements, such as "I would like learning with computers" and "I get a sinking feeling when I think of trying to use a computer." The individuals indicate the degree to which they agree with the statement on a five-point scale, with "agree strongly" on one end and "disagree strongly" on the other. Each response is given a value from 1 to 5, with 5 indicating a more positive attitude towards computers. Each of the three subscale scores is calculated by summing the scores of all the items for that scale, and a total score is calculated by adding the scores for all the items. This will also equal the sum of the three subscale scores. The total score and all three of the subscale scores was be used in this study. The anxiety scale has 9 items with a possible score ranging from 9 to 45, the confidence and liking scales each have 10 items with a possible score ranging from 10 to 50, giving a total possible score ranging from 29 to 145.

The Fennema-Sherman Mathematics Attitudes Scales are 10 separate scales designed to measure some domain-specific attitudes related to the learning of mathematics by all students. A study of 1,233 high school students found split-half reliability scores ranging from .86 to .93 (Fennema & Sherman, 1976; Broadbooks, 1981). In a study of 1,541 junior high school students, the authors concluded that their factor analysis provided "support for the theoretical structure" of the scales (Broadbooks, 1981). Each scale consists of 12 statements related to the learning of mathematics. Six are positively worded and six are negatively worded. Individuals respond to a statement by indicating the degree to which they agree or disagree with that statement. The possible responses are "strongly agree," "agree," "undecided," "disagree," and "strongly disagree." Each response is given a value from 1 to 5 with 5 indicating a more positive attitude. Each scale has a possible score of 12 to 60. When more than one scale is given, the items from each of the scales to be used are combined randomly to form one instrument. The scales used in this study are Confidence in Learning Mathematics, Mathematics Anxiety Scale, and the Effectance Motivation in Mathematics Scale. The scores from each of these scales were used in this study.

A questionnaire developed by the investigator and reviewed by the teachers, was used to obtain a measure of an individual's attitude towards the use of The Geometer's Sketchpad. This questionnaire was given to the students in the experimental group at the end of the study.

Population

The population for this study consisted of high school students enrolled in geometry courses.

Sample

The sample consisted of seven geometry classes of approximately 30 students each at a public high school in North Central Florida. Six of the classes were classified as Regular Geometry and one is classified as Advanced Geometry. The students were in grades 9 - 12 and are representative of the general population of area high school students enrolled in geometry courses. Thirty-eight students were enrolled in grade nine, 97 in grade ten, 48 in grade eleven and 22 in grade twelve. As required by county school board and university rules, teacher, student and parental permission was obtained for each student who participated in the study. Any student or a parent of any student could choose at any time not to have the student answer any of the questions in any of the attitude scales used in the study. They could also choose to have the student's responses and subsequent scores excluded from the study. The seven geometry classes were taught by three teachers: one taught a regular geometry class, one taught three regular geometry classes, and the third taught two regular geometry classes and an advanced geometry class.

The regular geometry class taught by the teacher who had only one geometry class served as the control group and received only the various instruments listed below. The students did not participate in any computer-based mathematics activities during the course of the study, but followed their regular schedule as determined by the teacher. The instruments and treatment (computer-based mathematics activities) were administered to the students in the other six classes. The five regular geometry classes in the experimental group did the same activities and covered approximately the same sections of the same textbook during the period of the study. The advanced geometry class used a different textbook and a separate set of activities were designed for this group. When this class covered the same topics as the regular geometry classes, identical or very similar activities were used. All classes in the experimental group spent the same amount of time in the computer laboratory during the course of the study.

General Procedure

Data were collected over a period of approximately eight weeks. During the first week of the study, the attitude scales were administered to the participants in each of the seven classes during a regularly scheduled class. The attitude scales were taken on a computer using a Filemaker Pro database that recorded and scored the responses. Students used either a Macintosh or IBM computer, with identical forms used on both. The student was not required to use the same computer model when taking the attitude scales the second time. During the next six weeks, the six experimental treatment classes supplemented their regular classroom activity with activities in the mathematics computer laboratory. The control class followed the regular schedule as determined by their teacher. Each treatment class attended the laboratory once a week as determined by the regular classroom teacher in conjunction with the investigator.

All of the computer-based activities involved participants' use of the Geometer's Sketchpad with activities tailored to promote and enhance students' readiness for self-directed learning. These activities were designed by the investigator with input from the participating teachers. They were designed to coincide with the topics and concepts that were covered in the regular classroom activities during subsequent days. Each activity included a worksheet and a Sketchpad file.

Each activity worksheet contained information about:

- the overall purpose for that activity;
- the name of the Sketchpad file to be used with that activity;
- problems to be solved and general directions for those problems.

On each activity worksheet the students recorded:

- general information on the students doing the activity, including names, class period, and the ID number of the computer used;
- students' responses to the various questions, information on how they solved the problems (including how they used the Geometer's Sketchpad), and which hints they used.

See Figure 3-1 for an example of an activity sheet. Each associated Sketchpad file contained information about:

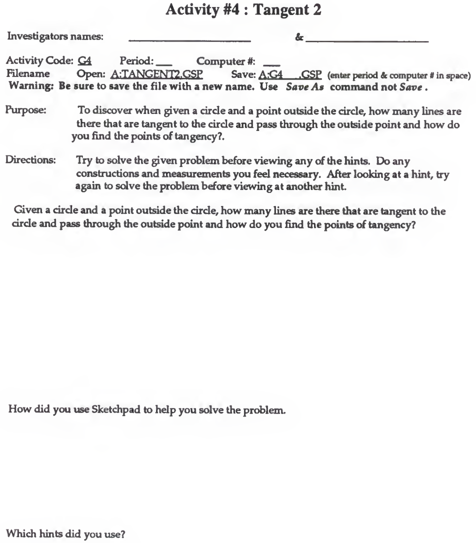
- statements of the problems to be solved;
- hints that are revealed sequentially by clicking buttons; (when the file is initially loaded, only the button for the first hint is visible; the buttons for each subsequent hint is only revealed when the previous hint has been displayed; the hints are progressive in nature in that use of each successive hint is dependent on the previous hints); the hint may contain modifications to the sketch;
- an initial sketch that was designed to serve as a logical starting point; (they are designed so that the sketch must be edited by moving objects, constructing objects, adding measurements, etc., to obtain the information needed to answer the questions); some of the files do not have an initial sketch.

When the Sketchpad file was saved to disk, the saved file contained:

- the latest version of the sketch incorporating any changes made to the original sketch;

- the hints that were revealed.

See Figure 3-2 for an example of a Sketchpad file. The Sketchpad file in Figure 3-2 is associated with the activity worksheet in Figure 3-1. See Appendix-A for more examples of activity worksheets and associated Sketchpad files.



Activity #4 : Tangent 2

Investigators names: ____________________ & ____________________

Activity Code: G4 Period: ___ Computer #: ___
Filename Open: A:TANGENT2.GSP Save: A:G4___.GSP (enter period & computer # in space)
Warning: Be sure to save the file with a new name. Use *Save As* command not *Save*.

Purpose: To discover when given a circle and a point outside the circle, how many lines are there that are tangent to the circle and pass through the outside point and how do you find the points of tangency?.

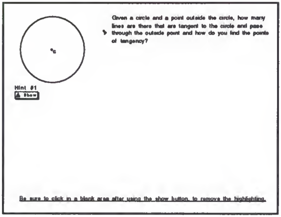
Directions: Try to solve the given problem before viewing any of the hints. Do any constructions and measurements you feel necessary. After looking at a hint, try again to solve the problem before viewing at another hint.

Given a circle and a point outside the circle, how many lines are there that are tangent to the circle and pass through the outside point and how do you find the points of tangency?

How did you use Sketchpad to help you solve the problem.

Which hints did you use?

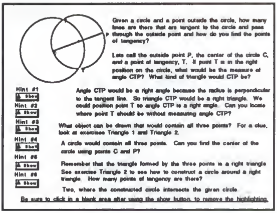
Figure 3 - 1. Example of Activity Worksheet



Given a circle and a point outside the circle, how many lines are there that are tangent to the circle and pass through the outside point and how do you find the points of tangency?

Be sure to click in a blank area after using the show button, to remove the highlighting.

Figure 3-2a



Given a circle and a point outside the circle, how many lines are there that are tangent to the circle and pass through the outside point and how do you find the points of tangency?

Lets call the outside point P, the center of the circle C, and a point of tangency, T. If point T is in the right position on the circle, what would be the measure of angle CTP? What kind of triangle would CTP be?

Angle CTP would be a right angle because the radius is perpendicular to the tangent line. So triangle CTP would be a right triangle. We could position point T so angle CTP is a right angle. Can you locate where point T should be without measuring angle CTP?

What object can be drawn that would contain all three points? For a clue, look at exercises Triangle 1 and Triangle 2.

A circle would contain all three points. Can you find the center of the circle using points C and P?

Remember that the triangle formed by the three points is a right triangle See exercise Triangle 2 to see how to construct a circle around a right triangle. How many points of tangency are there?

Two, where the constructed circle intersects the given circle

Be sure to click in a blank area after using the show button, to remove the highlighting.

Figure 3-2b

Figure 3 - 2. Example of Sketchpad File
a) Sketch after initial loading of file
b) Sketch after all the hints have been revealed

The students were free to manipulate and modify the sketch (move objects, construct objects, add measurements, etc.) in any manner they deemed necessary to solve the given problems. They were also free to view and use any of the hints. At the conclusion of the activity, students were to save the last version of the sketch to disk, using a unique filename incorporating the class period, activity number, and computer ID number. This served as a record of the modifications to the original sketch and the hints that were viewed.

The students worked in teams of two and at their own pace. They could work on as many activities during a class period as they desired and time permitted. They used an IBM computer running a Microsoft Windows version of the Geometer's Sketchpad.

During the last week of the study, the various attitude scales were again administered to the students in all seven classes during their regular scheduled class. The data were collected and analyzed as described in the research design.

Data

The following data were gathered:

Personal data: the gender and grade of each student.

Class data: identification codes for student's current geometry teacher and class period, grade point average in current geometry course for terms prior to study, grade point average in current geometry course for terms during and after completion of study, final exam scores for term after completion of study.

Survey data: pre- and post-measures of self-directed learning readiness, mathematics anxiety, mathematics confidence, mathematics effectance, computer anxiety, computer confidence, computer liking and overall computer attitude for each student and post measure of attitude towards The Geometer's Sketchpad. The Self-Directed Learning Readiness Scale (SDLRS), the Fennema-Sherman Mathematics Attitudes Scales and the Computer Attitude Scale (CAS) were used (see Instruments section for descriptions of instruments).

Data Analysis

Analysis of variance, analysis of loglikelihood and multiple regression were used to analyze the data. SDLRS scores collected at the beginning of the study were analyzed to identify any pre-existing differences between students grouped by experimental treatment, teacher, class period, grade or gender. The difference between SDLRS scores at the beginning and at the end of the study were analyzed to test for significant difference in the change in students' readiness for self-directed learning during the course of the study between students grouped by experimental treatment, teacher, class period, grade or gender.

Various multiple regression models were constructed and tested to identify those variables that significantly explain the variation in SDLRS scores. In each model the dependent variable was the difference between pre and post SDLRS scores. In one model, the independent variables were experimental treatment, attitude towards mathematics, attitude towards computers and terms for the interaction of those variables. The three Fennema-Sherman subscales were found to be highly correlated, and therefore a single measure of attitude towards mathematics was used. The three CAS subscales were also found to be highly correlated, and therefore a single measure of attitude towards computers was used. Another model contained the independent variables experimental treatment, ability in geometry, and a term for the interaction of those two variables. Grade point average in the geometry course for the year was used as measure of ability in geometry. A third model included attitude towards mathematics and attitude towards the Geometer's Sketchpad with a term for the interaction of those two variables as independent variables. The final model tested used attitude towards computers and attitude towards the Geometer's Sketchpad with a term for the interaction of those two variables as independent variables.

Geometry course and final exam grades served as the basis for the analysis of student performance in geometry during the course of the study. The study took place during the fourth quarter of the academic year. Students' performance in the course during that time was measured by their grade in the course for that term and the grade on the semester exam. Fourth quarter course grades and semester exam grades were analyzed to test for significant difference between students grouped by experimental treatment, teacher, class period, grade or gender.

Data collected at the beginning of the study were used to calculate correlations between the three Fennema-Sherman Mathematics Attitudes Scales, Mathematics Anxiety, Confidence in Learning Mathematics, and Effectance Motivation in Mathematics. All three scales were found to be highly correlated to each other. See Table 4-8 in Chapter 4. A total score was calculated by summing the three scale scores and this total score was used in all analysis incorporating attitude towards mathematics scores. Analysis of those total scores was analyzed to identify any pre-existing differences between students grouped by experimental treatment, teacher, class period, grade or gender. The difference between Fennema-Sherman total scores at the beginning and at the end of the study was analyzed to test for significant difference in the change in students' attitude towards mathematics during the course of the study between students grouped by experimental treatment, teacher, class period, grade or gender.

Correlations between the three Computer Attitudes Scales (CAS) scores, computer anxiety, computer confidence, computer liking, and overall total, were also calculated. All three scales were found to be highly correlated to each other. See Table 4-12. The total score was used in all analysis incorporating attitude towards computers scores. Analysis of those total scores was analyzed to identify any pre-existing differences between students grouped by experimental treatment, teacher, class period, grade or gender. The difference between CAS total scores at the beginning and at the end of the study was analyzed to test for significant difference in the change in students' attitude towards computers during the course of the study between students grouped by experimental treatment, teacher, class period, grade or gender.

Summary

The present study was designed to examine the influence of problem-solving activities using dynamic geometry computer software on an individual's readiness for self-directed learning. Other factors influencing an individual's readiness for self-directed learning, attitude towards mathematics and computers, were also studied.

The subjects in this study were students enrolled in seven geometry classes at a local high school. One class was designated as the control group and did not receive the experimental treatment. The other six classes were designated as the experimental group and did receive the experimental treatment. All the students were given the Self-Directed Learning Readiness Scale, three Fennema-Sherman Mathematics Attitudes Scales (Mathematics Anxiety, Confidence in Learning Mathematics, Effectance Motivation in Mathematics) and three Computer Attitudes Scales (computer anxiety, computer confidence, computer liking) at the beginning and the end of the study. At the end of the study, the students in the experimental group were given a survey of attitude towards the dynamic geometry computer software used in the study, The Geometer's Sketchpad. This survey was developed by the investigator. All the attitude surveys were administered by computer.

The experimental treatment consisted of a series of problem-solving activities designed to favor students' use of the Geometer's Sketchpad and tailored to promote and enhance students' readiness for self-directed learning. These activities were designed by the investigator with input from the participating teachers. They were designed to coincide with the topics and concepts that were covered in the regular classroom activities during subsequent days. The students in the experimental group visited the mathematics computer laboratory once a week for six weeks.

Analysis of variance, analysis of loglikelihood, correlations and multiple regression techniques was used to analyze the data. The results of data analyses are presented in Chapter 4 and discussed in Chapter 5.

CHAPTER 4
ANALYSIS OF THE DATA

The purpose of this study was to explore the relationship between computer technology and an individual's readiness for self-directed learning. Specifically, the study focused on the effects of problem-solving activities using dynamic geometry computer software on readiness for self-directed learning. Attitude towards mathematics, attitude towards computers, and their mediating effects were also explored.

Results

Analysis of variance, analysis of loglikelihood, correlations and multiple regression techniques was used to analyze the data.

Readiness for Self-directed Learning

The Self-Directed Learning Readiness Scales scores collected at the beginning of the study were analyzed to identify any pre-existing differences between students grouped by experimental treatment, teacher, class period, grade or gender. This data is summarized in Table 4-1.

Statistical analysis indicated no significant difference in SDLRS pre-study scores between any of these groups. The P values for experimental treatment, teacher, class period, grade and gender comparisons were .9903, .5678, .9498, .4585, .1615 respectively. The analysis of SDLRS pre-study scores by experimental treatment is summarized in Table 4-2. The other groups were analyzed similarly.

Table 4 - 1

SDLRS Pre Scores Summary

Exp.	N	Mean	Std Dev.	Low	High
0	22	213.5	22.22	177	258
1	151	213.4	25.31	147	274
Teacher	N	Mean	Std Dev.	Low	High
T1	76	215.6	25.36	147	274
T2	22	213.5	22.22	177	258
T3	75	211.3	25.23	149	263
Class	N	Mean	Std Dev.	Low	High
C1	22	213.2	24.01	155	247
C2	25	216.8	30.63	147	274
C3	29	216.3	21.92	165	260
C4	22	213.5	22.22	177	258
C5	18	211.6	31.51	149	263
C6	26	212.9	22.99	175	258
C7	31	209.7	23.72	167	263
Grade	N	Mean	Std Dev.	Low	High
9	32	219.5	23.16	165	261
10	70	210.9	26.90	147	274
11	26	212.4	24.23	170	262
12	19	213.0	23.96	177	252
Gender	N	Mean	Std Dev.	Low	High
F	95	215.84	22.97	155	263
M	78	210.51	26.88	147	274

Table 4 - 2

SDLRS Pre Scores by Experimental Treatment

Rsquare	9e-7
Root Mean Square Error	24.9489
Mean of Response	213.4393
Observations (or Sum Wgts)	173

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.09	0.093	0.0001
Error	171	106438.52	622.447	Prob>F
C Total	172	106438.61		0.9903

Mean Estimates

Level	N	Mean	Std Error
0	22	213.500	5.3191
1	151	213.430	2.0303

Means Comparisons (Tukey-Kramer HSD)

	0	1
0	-14.8487	-11.1689
1	-11.1689	-5.6677

Alpha = 0.05. Positive values show pairs of means that are significantly different.

The following hypotheses were generated to test for significant change in students' readiness for self-directed learning during the course of the study between students grouped by various variables and to identify significant interaction effects between those variables. The difference between SDLRS scores at the beginning and at the end of the study served as the basis for the analysis.

Hypothesis: There is no significant difference in the change in Self-Directed Learning Readiness Scale (SDLRS) scores between students grouped by teacher.

Hypothesis: There is no significant difference in the change in Self-Directed Learning Readiness Scale (SDLRS) scores between students grouped by class period.

Hypothesis: There is no significant difference in the change in Self-Directed Learning Readiness Scale (SDLRS) scores between students grouped by grade.

Hypothesis: There is no significant difference in the change in Self-Directed Learning Readiness Scale (SDLRS) scores between students grouped by gender.

The first four hypotheses may be combined in one statement for the sake of brevity. When practical in this chapter, several hypotheses will be combined in one statement.

Hypothesis 1a,b,c,d: There is no significant difference in the change in Self-Directed Learning Readiness Scale (SDLRS) scores between students grouped by teacher, class period, grade or gender.

The analysis of variance performed on the data yielded P values greater than the set alpha level of $p<.05$ level and the null hypotheses was accepted. The P values for teacher, class period, grade and gender comparisons were .8297, .2883, .5750, .5047 respectively.

Hypothesis 1e: There is no significant difference in the change in Self-Directed Learning Readiness Scale (SDLRS) scores between students grouped by experimental treatment.

The analysis of variance performed on the data yielded a P value of .9420. This is not significant at the set alpha level of $p<.05$ level and the null hypothesis was accepted. The ANOVA table is given in Table 4-3.

Table 4 - 3

Change in SDLRS Scores by Experimental Treatment

Rsquare	0.000035
Root Mean Square Error	19.39444
Mean of Response	-3.96078
Observations (or Sum Wgts)	153

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	2.000	2.000	0.0053
Error	151	56797.765	376.144	Prob>F
C Total	152	56799.765		0.9420

Mean Estimates

Level	number	Mean	Std Error
0	22	-3.68182	4.1349
1	131	-4.00763	1.6945

Means Comparisons (Tukey-Kramer HSD)

	0	1
0	-11.5538	-8.5033
1	-8.5033	-4.7348

Alpha = 0.05. Positive values show pairs of means that are significantly different.

Hypothesis 1f: There is no significant difference in the change in SDLRS scores between students grouped by experimental treatment due to interaction effect of experimental treatment and attitude towards mathematics and attitude towards computers.

Regression analysis showed no significant interaction between experimental treatment, attitude towards mathematics and attitude towards computers. The null hypothesis was accepted. The regression analysis table is given in Table 4-4.

Hypothesis 1g: There is no significant difference in the change in SDLRS scores between students grouped by experimental treatment due to interaction effect of experimental treatment and achievement in geometry.

This hypothesis was tested to see if the experimental treatment had the same effect on SDLRS scores for all levels of achievement in geometry. Students' grade point average in the course for the year was used as the measure of achievement in geometry. Regression analysis showed no significant interaction between experimental treatment and achievement in geometry. The null hypothesis was accepted. The regression analysis table is given in Table 4-5.

Hypothesis 1h: There is no significant change in SDLRS scores ~~due~~ due to interaction effect of experimental treatment and attitude towards mathematics and attitude towards the Geometer's Sketchpad.

Regression analysis showed no significant interaction between attitude towards mathematics and attitude towards the Geometer's Sketchpad. The null hypothesis was rejected. The regression analysis table is given in Table 4-6.

Table 4 - 4

Change in SDLRS Scores with Interaction Effects of Experimental Treatment, Attitude Towards Mathematics and Attitude Towards Computers

Rsquare	0.017309
Root Mean Square Error	20.27039
Mean of Response	-3.91912
Observations (or Sum Wgts)	136

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-51.38229	145.551	-0.35	0.7247
Exp.[1]	27.795535	151.289	0.18	0.8545
Math Tot Pre	0.3895072	1.25716	0.31	0.7572
Exp.[1]*Math Tot	-0.16746	1.29495	-0.13	0.8973
Comp Tot Pre	0.5052963	1.29228	0.39	0.6964
Exp.[1]*Comp Tot	-0.319683	1.34359	-0.24	0.8123
Math Tot*Comp Tot	-0.004025	0.01111	-0.36	0.7178
Exp.[1]*Math Tot*Comp Tot	0.0019542	0.01144	0.17	0.8647

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
Exp.	1	1	13.869471	0.0338	0.8545
Math Tot Pre	1	1	39.443643	0.0960	0.7572
Exp.*Math Tot	1	1	6.871280	0.0167	0.8973
Comp Tot Pre	1	1	62.821059	0.1529	0.6964
Exp.*Comp Tot	1	1	23.261071	0.0566	0.8123
Math Tot*Comp Tot	1	1	53.894564	0.1312	0.7178
Exp.*Math Tot*Comp Tot	1	1	11.984169	0.0292	0.8647

Table 4 - 5

Change in SDLRS Scores with Interaction Effects of Experimental Treatment and Ability in Geometry

Rsquare	0.029555
Root Mean Square Error	19.63251
Mean of Response	-3.97368
Observations (or Sum Wgts)	152

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-21	19.6325	-1.07	0.2866
Exp.[1]	14	20.8234	0.67	0.5025
Year GPA[1]	26	27.7646	0.94	0.3506
Year GPA[2]	-11.71429	20.988	-0.56	0.5776
Year GPA[3]	5.3809524	9.33712	0.58	0.5653
Year GPA[4] (Biased)	-5.63354	5.99251	-0.94	0.3488
Exp.[1]*Year GPA[1]	-26.43333	28.8426	-0.92	0.3610
Exp.[1]*Year GPA[2]	14.35974	21.5644	0.67	0.5065
Exp.[1]*Year GPA[3]	-0.745248	10.3557	-0.07	0.9427
Exp.[1]*Year GPA[4] (Zeroed)	0	0	•	•

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
Exp.	1	1	174.22222	0.4520	0.5025
Year GPA (Lost DFs)	4	3	505.71429	0.4374	0.7266
Exp.*Year GPA (Lost DFs)	4	3	328.27604	0.2839	0.8370

Table 4 - 6

Change in SDLRS Scores with Interaction Effects of Attitude Towards Mathematics and Attitude Towards The Geometer's Sketchpad

Rsquare	0.012813
Root Mean Square Error	20.08336
Mean of Response	-3.52991
Observations (or Sum Wgts)	117

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-46.35155	56.0064	-0.83	0.4096
Math Tot	0.2903007	0.40244	0.72	0.4722
Sketch	1.6035989	1.76408	0.91	0.3653
Math Tot*Sketch	-0.011096	0.01261	-0.88	0.3809

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
Math Tot Pre	1	1	209.87522	0.5203	0.4722
Sketch	1	1	333.29538	0.8263	0.3653
Math Tot*Sketch	1	1	312.05995	0.7737	0.3809

> Hypothesis 1i: There is no significant change in SDLRS scores due to interaction effect of attitude towards computers and attitude towards the Geometer's Sketchpad.

Regression analysis showed that the CAS total score was not a significant covariate. Attitude towards the Geometer's Sketchpad and interaction between attitude towards computers and attitude towards the Geometer's Sketchpad were found to be significant covariates. The null hypothesis was rejected. The regression analysis table is given in Table 4-7.

Table 4 - 7

Change in SDLRS Scores with Interaction Effects of Attitude Towards Computers and Attitude Towards The Geometer's Sketchpad

Rsquare	0.051014
Root Mean Square Error	19.54431
Mean of Response	-3.69167
Observations (or Sum Wgts)	120

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-96.89457	48.7801	-1.99	0.0494
Comp Tot	0.7029772	0.40417	1.74	0.0846
Sketch	3.6047369	1.66589	2.16	0.0325
Comp Tot*Sketch	-0.027684	0.0135	-2.05	0.0426

Effect Test

Source	Nparm	DF	Sum of Squares	F Ratio	Prob>F
Comp Tot	1	1	1155.5614	3.0252	0.0846
Sketch	1	1	1788.5285	4.6823	0.0325
Comp Tot*Sketch	1	1	1606.0850	4.2046	0.0426

Performance in Geometry

The following hypotheses test for significant differences in students' performance in geometry during the course of the study. The study took place during the fourth quarter of the academic year. Students' performance in the course during that time is reflected by their grade in the course for that term and the grade on the semester examination.

Hypothesis 2a: There is no significant difference in students' grade in geometry for the fourth quarter between students grouped by experimental treatment.

The analysis of loglikelihood performed on the data yielded a likelihood ratio chi-square P value of .1170. This is not significant at the set alpha level of p<.05 level and the null hypothesis was accepted. The analysis of loglikelihood table is given in Table 4-8.

Hypothesis 2b: There is no significant difference in students' grade in geometry on the second semester final examination between students grouped by experimental treatment.

The analysis of loglikelihood performed on the data yielded a likelihood ratio chi-square P value of .7162. This is not significant at the set alpha level of p<.05 level and the null hypothesis was accepted. The analysis of loglikelihood table is given in Table 4-9.

Attitude towards Mathematics

Correlations between the three Fennema-Sherman Mathematics Attitudes Scales, Mathematics Anxiety (A), Confidence in Learning Mathematics (C), and Effectance Motivation in Mathematics (E), were analyzed. Data collected at the beginning of the study was used. All three scales were found to be highly correlated to each other. See Table 4-10. A total score was calculated by summing the three scale scores and this total score was used in all analysis incorporating attitude towards mathematics scores.

Analysis of the data collected at the beginning of the study was analyzed to identify any pre-existing differences between students grouped by experimental treatment, teacher, class period, grade or gender. These are summarized in Table 4-11.

Table 4 - 8

Fourth Quarter Grade by Experimental Treatment

Rsquare (U)	0.011772
Observations (or Sum Wgts)	200

Analysis of LogLikelihood

Source	DF	–LogLikelihood
Model	4	3.69160
Error	192	309.89110
C Total	196	313.58270

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	7.383	0.1170
Pearson	7.640	0.1057

Table 4 - 9

Second Semester Final Examination Grade by Experimental Treatment

Rsquare (U)	0.003437
Observations (or Sum Wgts)	193

Analysis of LogLikelihood

Source	DF	–LogLikelihood
Model	4	1.05310
Error	185	305.37812
C Total	189	306.43122

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	2.106	0.7162
Pearson	2.302	0.6803

Table 4 - 10

Fennema-Sherman Mathematics Attitudes Scales Correlations

	Math A Pre	Math C Pre	Math E Pre
Math A Pre	1.0000	0.8808	0.6155
Math C Pre	0.8808	1.0000	0.6641
Math E Pre	0.6155	0.6641	1.0000

Table 4 - 11

Fennema-Sherman Pre Scores Summary

Exp.	N	Mean	Std Dev.	Low	High
0	20	115.5	23.26	81	156
1	123	127.8	26.43	55	178
Teacher	N	Mean	Std Dev.	Low	High
T1	67	127.0	26.76	63	170
T2	20	115.5	23.36	81	156
T3	56	128.8	26.35	55	178
Class	N	Mean	Std Dev.	Low	High
C1	19	117.4	25.48	67	162
C2	20	116.9	33.40	63	168
C3	28	140.8	13.93	114	170
C4	20	115.5	23.26	81	156
C5	13	135.4	28.84	71	166
C6	21	135.6	23.21	73	178
C7	22	118.4	25.11	55	160
Grade	N	Mean	Std Dev.	Low	High
9	30	136.3	20.13	74	170
10	63	121.3	29.04	55	169
11	17	120.5	21.25	72	144
12	11	113.9	25.84	67	155
Gender	N	Mean	Std Dev.	Low	High
F	81	126.6	25.74	63	178
M	62	125.4	27.19	55	168

Statistical analysis indicated no significant difference in Fennema-Sherman Mathematics Attitudes Scales total scores between students grouped by experimental treatment, teacher, grade or gender. The P values for experimental treatment, class period, grade and gender comparisons were .0506, .1390, .0552, .7854 respectively. Significant difference was found between students grouped by class period. The P value was .0005. The score for one class, the advanced geometry class, was found to be significantly higher than four of the other six classes. The two other classes had a different teacher than the advanced geometry class. In spite of the difference found between these classes, no significant difference was found between students grouped by teacher. The analysis of Fennema-Sherman Mathematics Attitudes Scales total scores by experimental treatment is summarized in Table 4-12. The other groups were analyzed similarly.

The following hypotheses were generated to test for significant change in students' attitude towards mathematics during the course of the study. The difference between Fennema-Sherman Mathematics Attitudes Scales total scores at the beginning and at the end of the study served as the basis for the analysis.

Hypothesis 3a,b,c: There is no significant difference in the change in Fennema-Sherman Mathematics Attitudes Scales total scores between students grouped by teacher, grade or gender.

The analysis of variance performed on the data yielded P values greater than the set alpha level of $p<.05$ level and the null hypotheses was accepted. The P values for teacher, grade and gender comparisons were .7698, .1106, .5438 respectively.

Table 4 - 12

Fennema-Sherman Mathematics Attitudes Scales Total Pre Scores by Experimental Treatment

Rsquare	0.026825
Root Mean Square Error	26.02713
Mean of Response	126.0909
Observations (or Sum Wgts)	143

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	2632.803	2632.80	3.8866
Error	141	95515.015	677.41	Prob>F
C Total	142	98147.818		0.0506

Mean Estimates

Level	number	Mean	Std Error
0	20	115.450	5.8198
1	123	127.821	2.3468

Means Comparisons (Tukey-Kramer HSD)

	1	0
1	-6.5612	-0.0345
0	-0.0345	-16.2711

Alpha = 0.05. Positive values show pairs of means that are significantly different.

Hypothesis 3d: There is no significant difference in the change in Fennema-Sherman Mathematics Attitudes Scales total scores between students grouped by class period.

The analysis of variance performed on the data yielded a significant overall difference between students grouped by class period. The P value was .7698.

The comparison for all pairs using Tukey-Kramer HSD indicated that one class period had a significantly greater decrease in total score than three of the other six classes. Two of those three class periods had different teachers. The null hypothesis was rejected. The analysis of Fennema-Sherman Mathematics Attitudes Scales total scores by class period is summarized in Table 4-13. The other groups were analyzed similarly.

> Hypothesis 3e: There is no significant difference in the change in Fennema-Sherman Mathematics Attitudes Scales total scores between students grouped by experimental treatment.

The analysis of variance performed on the data yielded a P value of .5129. This is not significant at the set alpha level of $p<.05$ level and the null hypothesis was accepted. The ANOVA table is given in Table 4-14.

Attitude towards Computers

Correlations between the four Computer Attitude Scale (CAS) scores were analyzed, computer anxiety (A), computer confidence (C), computer liking (L), and overall total (Tot). Data collected at the beginning of the study was used. All four scores were found to be highly correlated to each other. See Table 4-15. The CAS total score was used in all analysis incorporating attitude towards computers scores.

Analysis of the data collected at the beginning of the study was analyzed to identify any pre-existing differences between students grouped by experimental treatment, teacher, class period, grade or gender. These are summarized in Table 4-16.

Table 4 - 13

Change in Fennema-Sherman Mathematics Attitudes Scales Total Scores by Class Period

Rsquare	0.143345
Root Mean Square Error	16.19007
Mean of Response	-2.43357
Observations (or Sum Wgts)	143

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	6	5965.042	994.174	3.7928
Error	136	35648.076	262.118	Prob>F
C Total	142	41613.119		0.0016

Mean Estimates

Level	number	Mean	Std Error
C1	19	-1.7895	3.7143
C2	20	0.6000	3.6202
C3	28	-7.0000	3.0596
C4	20	-0.1000	3.6202
C5	13	-18.2308	4.4903
C6	21	-1.8095	3.5330
C7	22	6.6818	3.4517

Means Comparisons (Tukey-Kramer HSD)

	C7	C2	C4	C1	C6	C3	C5
C7	-14.6101	-8.8891	-8.1891	-6.7046	-6.2917	-0.1234	7.9614
C2	-8.8891	-15.3232	-14.6232	-13.1341	-12.7302	-6.5865	1.5676
C4	-8.1891	-14.6232	-15.3232	-13.8341	-13.4302	-7.2865	0.8676
C1	-6.7046	-13.1341	-13.8341	-15.7213	-15.3224	-9.1921	-0.9999
C6	-6.2917	-12.7302	-13.4302	-15.3224	-14.9539	-8.7976	-0.6792
C3	-0.1234	-6.5865	-7.2865	-9.1921	-8.7976	-12.9505	-5.0319
C5	7.9614	1.5676	0.8676	-0.9999	-0.6792	-5.0319	-19.0061

Alpha = 0.05. Positive values show pairs of means that are significantly different.

Table 4 - 14

Change in Fennema-Sherman Mathematics Attitudes Scales Total Scores by Experimental Treatment

Rsquare	0.003043
Root Mean Square Error	17.15315
Mean of Response	-2.43357
Observations (or Sum Wgts)	143

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	126.620	126.620	0.4303
Error	141	41486.499	294.230	Prob>F
C Total	142	41613.119		0.5129

Mean Estimates

Level	number	Mean	Std Error
0	20	-0.10000	3.8356
1	123	-2.81301	1.5466

Means Comparisons (Tukey-Kramer HSD)

	0	1
0	-10.7235	-5.4629
1	-5.4629	-4.3241

Alpha = 0.05. Positive values show pairs of means that are significantly different.

Table 4 - 15

Computer Attitude Scale (CAS) Correlations

	CAS A Pre	CAS C Pre	CAS L Pre	CAS Tot Pre
CAS A Pre	1.0000	0.8772	0.7376	0.9293
CAS C Pre	0.8772	1.0000	0.8200	0.9608
CAS L Pre	0.7376	0.8200	1.0000	0.9151
CAS Tot Pre	0.9293	0.9608	0.9151	1.0000

Table 4 - 16

Computer Attitude Scales Pre Scores Summary

Exp.	N	Mean	Std Dev.	Low	High
0	20	110.0	20.27	75	141
1	142	111.5	23.53	29	145
Teacher	N	Mean	Std Dev.	Low	High
T1	75	109.3	26.12	29	145
T2	20	110.0	20.27	75	141
T3	67	114.1	20.14	60	145
Class	N	Mean	Std Dev.	Low	High
T1	21	109.6	20.08	69	139
T2	25	112.6	30.80	29	145
T3	29	106.1	26.10	32	141
T4	20	110.0	20.27	75	141
T5	16	115.9	21.25	85	144
T6	24	110.8	22.86	60	145
T7	27	116.0	17.06	88	145
Grade	N	Mean	Std Dev.	Low	High
9	32	106.2	25.52	32	141
10	64	110.6	24.71	29	145
11	24	115.1	20.69	74	145
12	17	116.9	15.93	93	137
Gender	N	Mean	Std Dev.	Low	High
F	88	111.6	23.78	29	145
M	74	111.1	22.42	32	145

Statistical analysis indicated no significant difference in CAS total scores between students grouped by experimental treatment, teacher, class period, grade or gender. The P values for experimental treatment, teacher, class period, grade and gender comparisons were .7729, .4440, .7555, .3361, .8971. The analysis of CAS total scores by experimental treatment is summarized in Table 4-17. The other groups were analyzed similarly.

Table 4 - 17

CAS Total Pre Scores by Experimental Treatment

Rsquare	0.000522
Root Mean Square Error	23.1668
Mean of Response	111.3519
Observations (or Sum Wgts)	162

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	44.840	44.840	0.0835
Error	160	85872.105	536.701	Prob>F
C Total	161	85916.944		0.7729

Mean Estimates

Level	number	Mean	Std Error
0	20	109.950	5.1803
1	142	111.549	1.9441

Means Comparisons (Tukey-Kramer HSD)

	1	0
1	-5.4298	-9.3279
0	-9.3279	-14.4681

Alpha = 0.05. Positive values show pairs of means that are significantly different.

The following hypotheses were generated to test for significant change in students' attitude towards computers during the course of the study. The difference between CAS total scores at the beginning and at the end of the study served as the basis for the analysis.

Hypothesis 4a, b, c, d: There is no significant difference in the change in CAS total scores between students grouped by teacher, class period, grade or gender.

The analysis of variance performed on the data yielded P values greater than the set alpha level of $p<.05$ level and the null hypothesis was accepted. The P values for teacher, class period, grade and gender comparisons were .2487, .1912, .9696, .6618 respectively.

Hypothesis 4e: There is no significant difference in the change in CAS scores between students grouped by experimental treatment.

The analysis of variance performed on the data yielded a P value of .2203. This is not significant at the set alpha level of $p<.05$ level and the null hypothesis was accepted. The ANOVA table is given in Table 4-18.

Summary

This study addressed the following research questions:

1. Will doing problem-solving activities using dynamic geometry computer software (i.e. the Geometer's Sketchpad) make a difference in a student's readiness for self-directed learning?
2. Will doing problem-solving activities using dynamic geometry computer software (i.e. the Geometer's Sketchpad) make a difference in a student's performance in geometry?
3. Will doing problem-solving activities using dynamic geometry computer software (i.e. the Geometer's Sketchpad) make a difference in a student's attitude towards mathematics?
4. Will doing problem-solving activities using dynamic geometry computer software (i.e. the Geometer's Sketchpad) make a difference in a student's attitude towards computers?

Table 4 - 18

Change in CAS Total Scores by Experimental Treatment

Rsquare	0.010713
Root Mean Square Error	17.65389
Mean of Response	-7.74648
Observations (or Sum Wgts)	142

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	472.498	472.498	1.5161
Error	140	43632.375	311.660	Prob>F
C Total	141	44104.873		0.2203

Mean Estimates

Level	number	Mean	Std Error
0	19	-3.10526	4.0501
1	123	-8.46341	1.5918

Means Comparisons (Tukey-Kramer HSD)

	0	1
0	-11.3239	-3.2453
1	-3.2453	-4.4506

Alpha = 0.05. Positive values show pairs of means that are significantly different.

5. How are experience with computer-based mathematics tools, attitude towards mathematics and the learning of mathematics, attitude towards computers and using computers, and an individual's readiness for self-directed learning and mathematics achievement related to each other?

Results of the statistical analysis components of the study have been described in detail in this chapter and are summarized in this section. The findings and discussion of those findings, including limitations of this study and implications for further study, are discussed in Chapter 5.

The analyses of the data did not indicate that problem-solving activities using dynamic geometry computer software have a direct effect on readiness for self-directed learning in the given situation. Similarly there was no indication that problem-solving activities using dynamic geometry computer software have a direct effect on attitude towards computers or mathematics. Analyses of student performance in geometry as measured by course grades for the quarter and the semester final examination did not show any effect from the experimental treatment.

Regression analyses were performed to identify any significant interaction among experimental treatment, attitude towards mathematics, attitude towards computers, performance in geometry, attitude towards the Geometer's Sketchpad. Significant interaction was found between attitude towards computers and attitude towards the Geometer's Sketchpad. Attitude towards the Geometer's Sketchpad was also found to be a significant covariate in the same model. No significant interaction was found between experimental treatment, attitude towards mathematics, attitude towards computers, or performance in geometry.

CHAPTER 5
SUMMARY AND CONCLUSIONS

Overview of the Study

The purpose of this study was to explore the relationships between computer technology and an individual's readiness for self-directed learning. Specifically, the study focused on the effects of problem-solving activities using dynamic geometry computer software on readiness for self-directed learning. Attitude towards mathematics, attitude towards computers, and their mediating effects were also explored. Seven intact geometry classes in a local high school participated in the study. Six of the classes were designated as the experimental group and received the experimental treatment. The other class served as the control group. Students in the experimental group visited the mathematics computer laboratory once a week for a period of six weeks. In the laboratory they received a set of problem-solving activities that were designed to be used with The Geometer's Sketchpad.

At the beginning and at the end of the study, the participants completed a set of surveys that measure individuals' readiness for self-directed learning and attitude towards mathematics and computers. The instruments used were the Self-Directed Learning Readiness Scale (SDLRS), Computer Attitude Scale (CAS), and the Fennema-Sherman Mathematics Attitudes Scales. The investigator gathered additional information — grade, sex, teacher, and class period — for each student. At the end of the study, the students in the experimental group completed a survey of attitude towards

The Geometer's Sketchpad. Class grades for all the participating students were gathered for the grading period encompassing the period of study and included the quarter grades for that term and grades for the semester final given at the conclusion of that term. Average grades in the course for the year were calculated.

Findings

The research questions that were addressed by this study are listed below. Following each question is a general statement of the hypotheses pertaining to that question that were statistically tested. An expanded list of questions and hypotheses can be found in the Research Questions section in Chapter 3.

1. Will doing problem-solving activities using dynamic geometry computer software (i.e. the Geometer's Sketchpad) make a difference in a student's readiness for self-directed learning?

   Hypotheses: There is no significant difference in the change in Self-Directed Learning Readiness Scale (SDLRS) scores between students grouped by experimental treatment, teacher, class period, grade or gender.

No significant difference was found between any of the groups, and the hypotheses were accepted. Analysis of the SDLRS scores at the beginning of the study showed an average score of 213.5 for the control group and 213.4 for the experimental group. Analysis of the SDLRS scores at the end of the study showed that the average change in SDLRS scores was -4.00763 for the experimental group and -3.68182 for the control group. (See Table 4-2 in Chapter 4.) Though the experimental group had a greater average decrease in SDLRS scores than the control group, this difference was not statistically significant. Further statistical analysis of SDLRS scores showed no significant difference between the SDLRS pre and post scores within the experimental, within the control group, or overall. It is concluded that not only did the experimental treatment have no direct effect on SDLRS scores, but neither did any other factor.

2. Will doing problem-solving activities using dynamic geometry computer software (i.e. the Geometer's Sketchpad) make a difference in a student's performance in geometry?

   Hypotheses: There is no significant difference in grades received in the geometry course between students grouped by experimental treatment.

No significant difference was found between any of the groups and the hypotheses were accepted.

3. Will doing problem-solving activities using dynamic geometry computer software (i.e. the Geometer's Sketchpad) make a difference in students' attitude towards mathematics?

   Hypotheses: There is no significant difference in the change in Fennema-Sherman Mathematics Attitudes Scales scores between students grouped by experimental treatment, teacher, class period, grade or gender.

No significant difference in Fennema-Sherman Mathematics Attitudes Scales total scores was found between students grouped by experimental treatment, teacher, grade or gender. One class period had a significantly greater decrease in total score than three of the other six classes. The two other classes had a different teacher than the advanced geometry class. In spite of the difference found between these classes, no significant difference was found between students grouped by teacher. Four of the five hypotheses were accepted.

4. Will doing problem-solving activities using dynamic geometry computer software (i.e. the Geometer's Sketchpad) make a difference in a student's attitude towards computers?

   Hypotheses: There is no significant difference in the change in Computer Attitude Scale scores between students grouped by experimental treatment, teacher, class period, grade or gender.

No significant difference was found between any of the groups and the hypotheses were accepted.

5. How are experience with computer-based mathematics tools, attitude towards mathematics and the learning of mathematics, attitude towards computers and using computers, and an individual's readiness for self-directed learning and mathematics achievement related to each other?

   Hypotheses: There is no significant difference in the change in SDLRS scores between students grouped by experimental treatment due to interaction effect of experimental treatment and achievement in geometry, attitude towards mathematics, attitude towards, and/or attitude towards The Geometer's Sketchpad.

No significant interaction between experimental treatment, attitude towards mathematics and attitude towards computers was found. Nor was significant interaction between experimental treatment and achievement in geometry found. Significant interaction between attitude towards mathematics and attitude towards the Geometer's Sketchpad was also not found. But interaction between attitude towards computers and attitude towards the Geometer's Sketchpad were found to be significant covariates. See Table 4-6 in Chapter 4.

Discussion

Knowles states that "the main purpose of education must now be to develop the skills of inquiry" (1975, p. 15). This certainly coincides with the emphasis of self-directed learning on "independent thinking over an inordinate dependence on *what I have been told*" (Dirkes, 1993, p. 20). There is also a natural link between self-directed learning and constructivism. Constructivism is based on the notion that individuals construct their own knowledge. Since computers are often described as a "tool to think with," it would be natural to investigate the effect of using the computer as a tool on individuals' ability and desire for "independent thinking", constructing their own knowledge, and, in turn, self-directed learning.

This study focused on the use of The Geometer's Sketchpad computer software in doing problem-solving activities and the effect on students' readiness for self-directed learning. The Geometer's Sketchpad is an example of dynamic geometry software, a type of computer-based mathematics tool that has become increasingly popular in mathematics education, particularly in secondary school geometry. This type of software allows for direct construction, manipulation, and measurement of geometric figures. The effect of using The Geometer's Sketchpad on attitude towards the learning of mathematics, the use of computers, and their mediating effects were also explored.

The results of the study do not indicate that problem-solving activities using dynamic geometry computer software had a direct effect on readiness for self-directed learning. The results did show a slight, but not statistically significant, drop in SDLRS scores. This drop occurred almost equally in the experimental and control groups. There was also a slight drop in both groups in scores measuring attitude towards mathematics and computers. These drops were also found not to be statistically significant. But these results do lead to the following questions.

1. Is there an indication here that there may have been a decline in attitudes in these areas?

2. Are there other factors that would explain why there was no increase in students' readiness for self-directed learning?

3. Can it be concluded that there is no relationship between using dynamic geometry computer software and readiness for self-directed learning?

One factor that may have skewed the attitude scores was that the post-study attitude surveys were administered during the week prior to final examination week, which was also the last week of the school year. The investigator noted that several students exhibited displeasure in doing the surveys. "Do we have to this again?" was expressed by several students. The teachers were not surprised by these remarks and stated a belief that students' attitudes and moods generally decline at that time of the school year. They stated that students were concerned mainly with their upcoming exams and were generally not enthusiastic to do any "extra" work.

Are there other factors that would explain why there was no increase in students' readiness for self-directed learning? An informal analysis of the activity worksheets did not indicate that the problems were unusually difficult. The activities and problems were not designed with an expectation that the average student would be able to successfully complete most of the activities, and they did not. The teachers expressed a general approval of the activities and students' experiences with them, but no formal analysis of student performance on the activities was attempted. Not enough of the

Sketchpad activity files were saved properly to allow for any analysis of students' ability and experience with using The Geometer's Sketchpad. This precluded any formal analysis of how the use of, or ability with, The Geometer's Sketchpad affected students' performance on the problem-solving activities. Informal observations by the investigator and the teachers revealed that at times a student was not exactly sure of "what to do" or how to use the software to do what they wanted to do. There were also many examples of students "catching on." The very limited prior exposure to the use of The Geometer's Sketchpad, limited time spent on the activities, and unfamiliarity with constructivist-type problems and activities may have inhibited or reduced any effect on students' readiness for self-directed learning.

Can it be concluded that there is no relationship between using dynamic geometry computer software and readiness for self-directed learning? Attitude towards The Geometer's Sketchpad and interaction between attitude towards computers and attitude towards The Geometer's Sketchpad were found to be significant covariates in a model of the change in SDLRS scores. The parameter estimate for the attitude towards The Geometer's Sketchpad was greater than zero, indicating that a positive change in attitude towards The Geometer's Sketchpad would help produce a positive change in SDLRS scores. This would infer that there is a positive relationship between using dynamic geometry computer software and readiness for self-directed learning through the mediating effects of attitude towards dynamic geometry computer software.

Implications

The results of the study did not indicate that problem-solving activities using dynamic geometry computer software had an effect on readiness for self-directed learning, attitude towards mathematics or attitude towards computers. There is, however, an indication of a positive relationship between using dynamic geometry computer software and readiness for self-directed learning through the mediating effects of attitude towards dynamic geometry computer software. It may be that attitude towards the type of computer software or the particular software being used, not the general attitude towards computers, is a significant factor in any attempt to promote readiness for self-directed learning. Analyzing general attitude towards computers when exploring the effects of attitude towards the use the of computer technology, may hide a real effect by the type of computer software or the particular software being used. Further study is needed to prove or disprove this generalization.

A positive relationship between using dynamic geometry computer software and readiness for self-directed learning through the mediating effects of attitude towards dynamic geometry computer software would indicate that the tools, including computer-based tools, that are available to the learner affects their readiness for self-directed learning.

Replication of the Study

It is recommended that this study be replicated under other conditions before the results of the study are generalized to other situations. Certain conditions in the present study may make such generalizations difficult.

As indicated above, the time of the study may have interfered with the treatment effect. It is recommended that the study be scheduled so that the collection of attitude data does not take place immediately prior to or after the administration of any major examination such as a semester exam. The anxiety normally associated with testing may skew any attitudinal data.

Also, as stated above, the very limited prior exposure to the use of The Geometer's Sketchpad, and unfamiliarity with constructivist-type problems and activities may have inhibited or reduced any treatment effect. It is recommended that the teachers involved in the study incorporate constructivist or investigative activities using The Geometer's Sketchpad in the normal classroom activities prior to student use in the laboratory. Without such prior exposure, students may not have sufficient sense or understanding of learning by inquiry to make effective use of tools such as The Geometer's Sketchpad.

Other conditions such as a formal training period in the use of The Geometer's Sketchpad may also be altered. These are outlined in the recommendations for future studies section below.

Recommendations

The following recommendations are made for future studies of the relationship between readiness for self-directed learning and the use of dynamic geometry software or any other computer technology:

1. Develop and validate a formal measure of attitude towards the use of The Geometer's Sketchpad and use it to investigate the use of such software on readiness for self-directed learning . A measure of attitude towards dynamic geometry software or the use of a computer as a mathematics investigation tool may be sufficient. Individuals' attitude

towards a specific piece or type of software may be significantly different from their general attitude towards computers.

2. Develop and validate a formal measure of ability in the use of The Geometer's Sketchpad and use it to investigate the use of such software on readiness for self-directed learning. It seem logical that use of a tool cannot have a positive effect when the individual does not have the ability and understanding necessary to use the tool efficiently. A formal measure of ability can be used as a covariate in any study and may indicate an effect that may otherwise be hidden.

3. Vary the frequency and/or length of the activities that incorporate the use of the computer technology. Any positive effect may be so gradual that a longer study is needed to detect it. It is also possible that more frequent use will reinforce any positive effect.

4. Provide a period of student training in the use of computer technology in question as a learning or investigative tool before the start of the treatment. This may help identify the level of opportunity for the students to gain the level of necessary ability and understanding of using The Geometer's Sketchpad or other computer tools.

5. Study the effect of teacher use of the computer technology in the teaching of the subject matter on subsequent student use. "Teacher use of the software" does not include direct demonstration of or instruction in how the student could or should use the computer or do the activities. The important aspect here is to see whether students gain an understanding of the use of computer technology as a learning or investigative tool from the similar use by the teacher as part of the "normal" teaching method. If we want students to learn by inquiry in a computer laboratory, inquiry using the same computer technology should be a normal part of the classroom environment.

6. Study the effect of prior experience with one type of mathematics tool in one subject area on use of another type of mathematics tool in another subject area could be studied. For example, does having experience with using a graphing calculator in the study of algebra affect the use of The Geometer's Sketchpad in the study of geometry and visa versa? This may help to understand if students' understanding of the use of computer technology as a learning or investigative tool is a gradual process that is dependent on prolonged exposure to and/or experience with such use.

Summary

Self-directed learning is gaining emphasis as an important aspect of the learning of mathematics and learning in general. Computer technology plays an ever-increasing role in creating learning environments that promote self-directed learning. Research is needed to help guide how that computer technology can be best utilized.

Computer-based mathematics tools can be designed to help students investigate, discover and construct their own knowledge and understanding. In the learning of geometry, dynamic geometry software such as The Geometer's Sketchpad and Cabri are examples of such a mathematics tool. By direct construction, manipulation, and measurement of geometric figures, students have an increased ability to direct and conduct their own investigations. They are not limited by their own ability, or lack of ability, to mentally visualize and/or calculate the data necessary to test their own conjectures. If students feel they have the means to test their conjectures in a non-threatening environment, then it would seem logical that they would be more likely to conjecture and conjecture more soundly . This environment is non-threatening in that students discover contradictions that naturally result from erroneous conjectures and then are free to modify and re-test their conjectures. They do not simply discover that their answer does not match the "correct" answer.

This study was designed to investigate the effects of problem-solving activities using dynamic geometry computer software on readiness for self-directed learning. Attitude towards mathematics, attitude towards computers, and their mediating effects were also explored. Though this study did not show any direct effect on readiness for self-directed learning or attitude towards mathematics and computers, it did show evidence of a positive relationship between using dynamic geometry computer software and readiness for self-directed learning through the mediating effects of attitude towards dynamic geometry computer software.

The attitudes, values and abilities that constitute an individual's readiness for self-directed learning indicates that it is a function of many factors or variables. This study supports the notion that one of the independent variables in this function is the tools available to the learner, including computer-based tools.

APPENDIX A
SAMPLE ACTIVITY WORKSHEETS AND SKETCHPAD FILES

The Geometer's Sketchpad activities used in this study were designed by the investigator with input from the participating teachers. They were designed to coincide with the topics and concepts that were covered in the regular classroom activities during subsequent days. There is an activity sheet and a Sketchpad file for each activity.

Each activity worksheet contained information about:

- the overall purpose for that activity;
- the name of the Sketchpad file to be used with that activity;
- problems to be solved and general directions for those problems.

On each activity worksheet the students recorded:

- general information on the students doing the activity, including names, class period, and the ID number of the computer used;
- students' responses to the various questions, information on how they solved the problems (including how they used the Geometer's Sketchpad), and which hints they used.

Each associated Sketchpad file contained information about:

- statements of the problems to be solved;
- hints that are revealed sequentially by clicking buttons; (when the file is initially loaded, only the button for the first hint is visible; the buttons for each subsequent hint is only revealed when the previous hint has been displayed; the hints are progressive in nature in that use of each successive hint is dependent on the previous hints); the hint may contain modifications to the sketch;

- an initial sketch that was designed to serve as a logical starting point; (they are designed so that the sketch must be edited by moving objects, constructing objects, adding measurements, etc., to obtain the information needed to answer the questions); some of the files do not have an initial sketch.

When the Sketchpad file was saved to disk, the saved file contained:

- the latest version of the sketch incorporating any changes made to the original sketch;
- the hints that were revealed.

The students were free to manipulate and modify the sketch (move objects, construct objects, add measurements, etc.) in any manner they deemed necessary to solve the given problems. They were also free to view and use any of the hints. At the conclusion of the activity, students were to save the last version of the sketch to disk, using a unique filename incorporating the class period, activity number, and computer ID number. This served as a record of the modifications to the original sketch and the hints that were viewed.

The following pages contain examples of some of the activity worksheets and associated Sketchpad files. Each example includes a figure of the actual worksheet as seen by the students followed by two figures illustrating the Sketchpad files as it appears on the screen inside the Sketchpad window. The figures have been reduced to fit the margins of this document. The first Sketchpad figure shows the file after initial opening. The other figure shows the file after all the hints have been revealed. The first example contains an additional Sketchpad figure in the between the other two figures showing the file after the first hint has been viewed. The first four example activities were used with the regular geometry classes and the last two with the advanced geometry class.

Activity #4 : Tangent 2

Investigators names: ____________________ & ____________________

Activity Code: G4 Period: ___ Computer #: ___
Filename Open: A:TANGENT2.GSP Save: A:G4 .GSP (enter period & computer # in space)
Warning: Be sure to save the file with a new name. Use *Save As* command not *Save*.

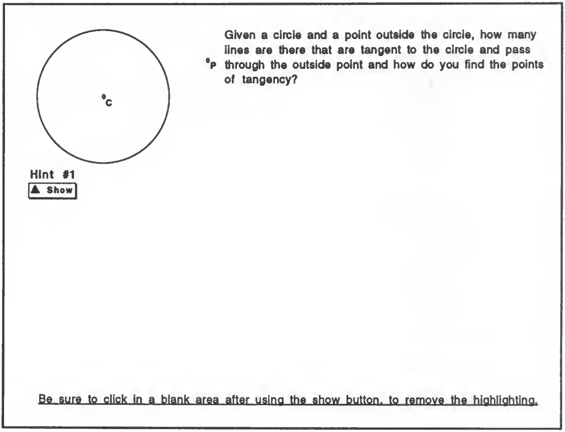
Purpose: To discover when given a circle and a point outside the circle, how many lines are there that are tangent to the circle and pass through the outside point and how do you find the points of tangency?.

Directions: Try to solve the given problem before viewing any of the hints. Do any constructions and measurements you feel necessary. After looking at a hint, try again to solve the problem before viewing at another hint.

Given a circle and a point outside the circle, how many lines are there that are tangent to the circle and pass through the outside point and how do you find the points of tangency?

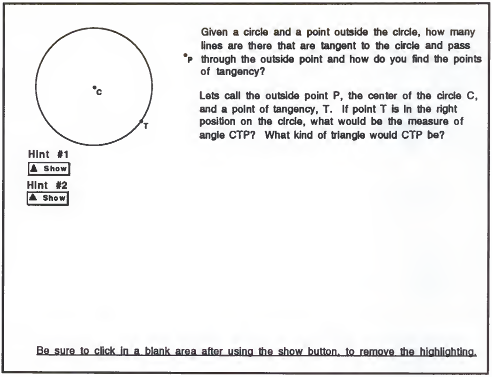
How did you use Sketchpad to help you solve the problem.

Which hints did you use?



Given a circle and a point outside the circle, how many lines are there that are tangent to the circle and pass through the outside point and how do you find the points of tangency?

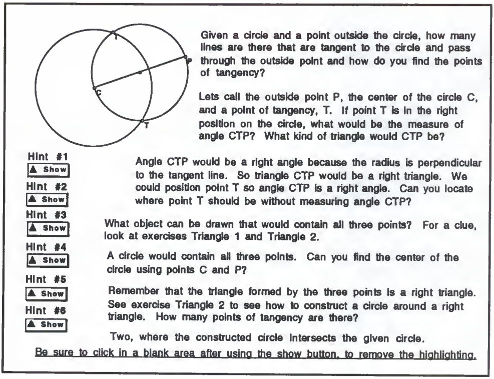
Be sure to click in a blank area after using the show button, to remove the highlighting.



Given a circle and a point outside the circle, how many lines are there that are tangent to the circle and pass through the outside point and how do you find the points of tangency?

Lets call the outside point P, the center of the circle C, and a point of tangency, T. If point T is in the right position on the circle, what would be the measure of angle CTP? What kind of triangle would CTP be?

Be sure to click in a blank area after using the show button, to remove the highlighting.



Given a circle and a point outside the circle, how many lines are there that are tangent to the circle and pass through the outside point and how do you find the points of tangency?

Lets call the outside point P, the center of the circle C, and a point of tangency, T. If point T is in the right position on the circle, what would be the measure of angle CTP? What kind of triangle would CTP be?

Angle CTP would be a right angle because the radius is perpendicular to the tangent line. So triangle CTP would be a right triangle. We could position point T so angle CTP is a right angle. Can you locate where point T should be without measuring angle CTP?

What object can be drawn that would contain all three points? For a clue, look at exercises Triangle 1 and Triangle 2.

A circle would contain all three points. Can you find the center of the circle using points C and P?

Remember that the triangle formed by the three points is a right triangle. See exercise Triangle 2 to see how to construct a circle around a right triangle. How many points of tangency are there?

Two, where the constructed circle intersects the given circle.

Be sure to click in a blank area after using the show button, to remove the highlighting.

Activity #11 : Area 2

Investigators names: ____________________ & ____________________

Activity Code: G11 Period: ___ Computer #: ___
Filename Open: A:AREA2.GSP Save: A:G11___.GSP (enter period & computer # in space)
Warning: Be sure to save the file with a new name. Use *Save As* command not *Save.*

Purpose: To prove that the area of a rectangle and a parallelogram are both computed by width times height.

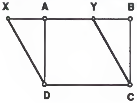
Directions: Try to solve the given problem before viewing any of the hints. Do any constructions and measurements you feel necessary. After looking at a hint, try again to solve the problem before viewing at another hint.

How do the widths, heights and areas of rectangle ABCD and parallelogram XYCD compare?

How does the areas of triangles XAD and YBC compare? Verify that using the measuring capabilities of Sketchpad.

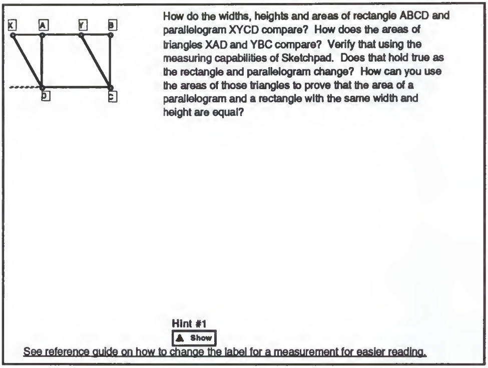
Does that hold true as the rectangle and parallelogram change?

How can you use the areas of those triangles to prove that the area of a parallelogram and a rectangle with the same width and height are equal?



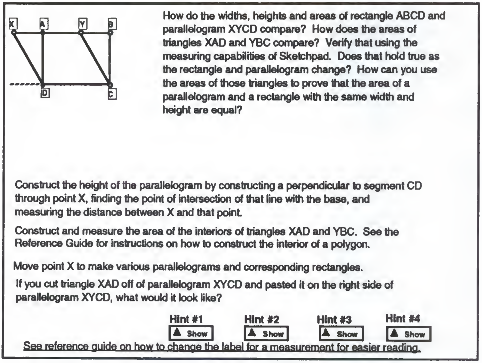
How did you use Sketchpad to help you solve the problem.

Which hints did you use?



How do the widths, heights and areas of rectangle ABCD and parallelogram XYCD compare? How does the areas of triangles XAD and YBC compare? Verify that using the measuring capabilities of Sketchpad. Does that hold true as the rectangle and parallelogram change? How can you use the areas of those triangles to prove that the area of a parallelogram and a rectangle with the same width and height are equal?

See reference guide on how to change the label for a measurement for easier reading.



How do the widths, heights and areas of rectangle ABCD and parallelogram XYCD compare? How does the areas of triangles XAD and YBC compare? Verify that using the measuring capabilities of Sketchpad. Does that hold true as the rectangle and parallelogram change? How can you use the areas of those triangles to prove that the area of a parallelogram and a rectangle with the same width and height are equal?

Construct the height of the parallelogram by constructing a perpendicular to segment CD through point X, finding the point of intersection of that line with the base, and measuring the distance between X and that point.

Construct and measure the area of the interiors of triangles XAD and YBC. See the Reference Guide for instructions on how to construct the interior of a polygon.

Move point X to make various parallelograms and corresponding rectangles.

If you cut triangle XAD off of parallelogram XYCD and pasted it on the right side of parallelogram XYCD, what would it look like?

See reference guide on how to change the label for a measurement for easier reading.

Activity #12 : Triangle Area 1

Investigators names: ____________________ & ____________________

Activity Code: G12 Period: ___ Computer #: ___
Filename Open: A:TRIAREA1.GSP Save: A:G12___.GSP (enter period & computer # in space)
Warning: Be sure to save the file with a new name. Use *Save As* command not *Save*.

Purpose: To discover relationships between the area of a rectangle and a triangle.

Directions: Try to solve the given problem before viewing any of the hints. Do any constructions and measurements you feel necessary. After looking at a hint, try again to solve the problem before viewing at another hint.

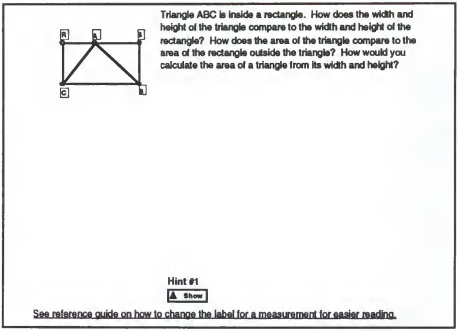
Triangle ABC is inside a rectangle. How does the width and height of the triangle compare to the width and height of the rectangle?

How does the area of the triangle compare to the area of the rectangle outside the triangle?

How would you calculate the area of a triangle from its width and height?

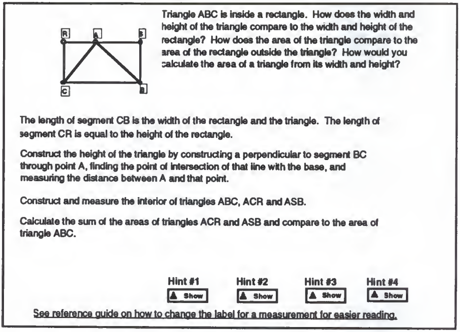
How did you use Sketchpad to help you solve the problem.

Which hints did you use?



Triangle ABC is inside a rectangle. How does the width and height of the triangle compare to the width and height of the rectangle? How does the area of the triangle compare to the area of the rectangle outside the triangle? How would you calculate the area of a triangle from its width and height?

See reference guide on how to change the label for a measurement for easier reading.



Triangle ABC is inside a rectangle. How does the width and height of the triangle compare to the width and height of the rectangle? How does the area of the triangle compare to the area of the rectangle outside the triangle? How would you calculate the area of a triangle from its width and height?

The length of segment CB is the width of the rectangle and the triangle. The length of segment CR is equal to the height of the rectangle.

Construct the height of the triangle by constructing a perpendicular to segment BC through point A, finding the point of intersection of that line with the base, and measuring the distance between A and that point.

Construct and measure the interior of triangles ABC, ACR and ASB.

Calculate the sum of the areas of triangles ACR and ASB and compare to the area of triangle ABC.

See reference guide on how to change the label for a measurement for easier reading.

Activity #16 : Circle Area

Investigators names: ____________________ & ____________________

Activity Code: G16 Period: ___ Computer #: ___
Filename Open: A:CIRCLE1.GSP Save: A:G16___.GSP (enter period & computer # in space)
Warning: Be sure to save the file with a new name. Use *Save As* command not *Save.*

Purpose: To discover the relationship between the area of a circle and the area of a regular polygon

Directions: Try to solve the given problem before viewing any of the hints. Do any constructions and measurements you feel necessary. After looking at a hint, try again to solve the problem before viewing at another hint.

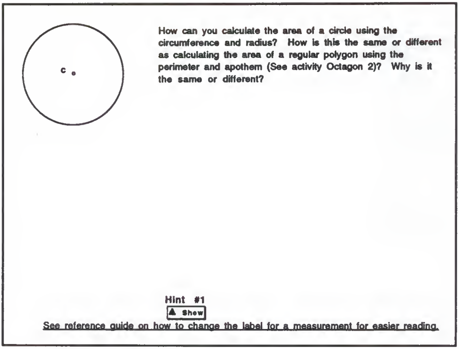
One way to calculate the area of a circle is one-half pi times the radius squared. Find another way to find the area using the circumference and radius?

How can you use Sketchpad to verify this works for all circles?

How is this the same or different as calculating the area of a regular polygon using the perimeter and apothem (See activity Octagon 2)? Why is it the same or different?

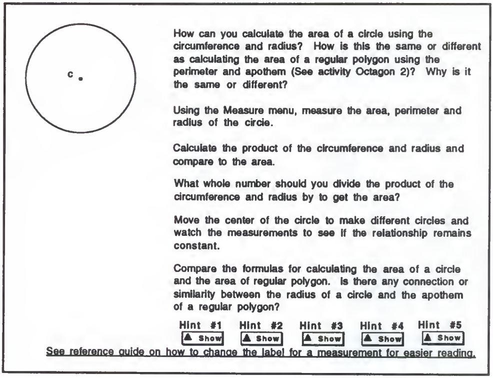
How did you use Sketchpad to help you solve the problem.

Which hints did you use?



How can you calculate the area of a circle using the circumference and radius? How is this the same or different as calculating the area of a regular polygon using the perimeter and apothem (See activity Octagon 2)? Why is it the same or different?

See reference guide on how to change the label for a measurement for easier reading.



How can you calculate the area of a circle using the circumference and radius? How is this the same or different as calculating the area of a regular polygon using the perimeter and apothem (See activity Octagon 2)? Why is it the same or different?

Using the Measure menu, measure the area, perimeter and radius of the circle.

Calculate the product of the circumference and radius and compare to the area.

What whole number should you divide the product of the circumference and radius by to get the area?

Move the center of the circle to make different circles and watch the measurements to see if the relationship remains constant.

Compare the formulas for calculating the area of a circle and the area of regular polygon. Is there any connection or similarity between the radius of a circle and the apothem of a regular polygon?

See reference guide on how to change the label for a measurement for easier reading.

Activity #8 : Area Ratio 3

Investigators names: ____________________ & ____________________

Activity Code: A8 Period: ___ Computer #: ___
Filename Open: A:RATIO3.GSP Save: A:A8 .GSP (enter period & computer # in space)
Warning: Be sure to save the file with a new name. Use *Save As* command not *Save.*

Purpose: To discover a special characteristic of the areas of two similar figures

Directions: Try to solve the given problem before viewing any of the hints. Do any constructions and measurements you feel necessary. After looking at a hint, try again to solve the problem before viewing at another hint.

How are the ratios of their perimeters and areas related to the scale factor of the two figures?

Is this true for any two simlar figures with the same scale factor?

How can you verify that using Sketchpad?

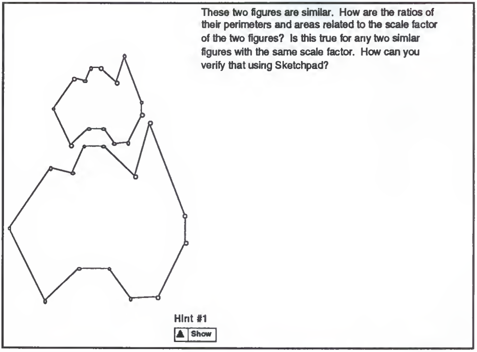
If the scale factor of two similar figures is *a:b*, then

the ratio of the perimeters is ____________ and

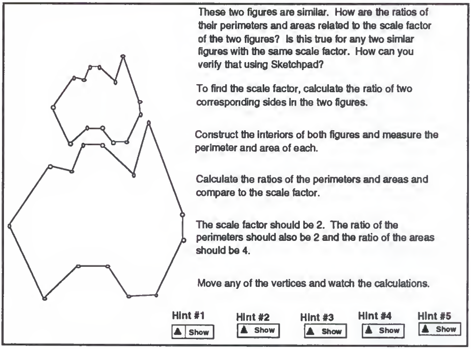
the ratio of the areas is ____________ .

How did you use Sketchpad to help you solve the problem.

Which hints did you use?



These two figures are similar. How are the ratios of their perimeters and areas related to the scale factor of the two figures? Is this true for any two simlar figures with the same scale factor. How can you verify that using Sketchpad?



These two figures are similar. How are the ratios of their perimeters and areas related to the scale factor of the two figures? Is this true for any two simlar figures with the same scale factor. How can you verify that using Sketchpad?

To find the scale factor, calculate the ratio of two corresponding sides in the two figures.

Construct the interiors of both figures and measure the perimeter and area of each.

Calculate the ratios of the perimeters and areas and compare to the scale factor.

The scale factor should be 2. The ratio of the perimeters should also be 2 and the ratio of the areas should be 4.

Move any of the vertices and watch the calculations.

Activity #18 : Triangle Segment Locus

Investigators names: ____________________ & ____________________

Activity Code: A18 Period: ___ Computer #: ___
Filename Open: A:LOCITRI.GSP Save: A:A18 .GSP (enter period & computer # in space)
Warning: Be sure to save the file with a new name. Use *Save As* command not *Save*.

Purpose: To discover the locus of the midpoints of a segment from a vertex of a triangle to the opposite side

Directions: Try to solve the given problem before viewing any of the hints. Do any constructions and measurements you feel necessary. After looking at a hint, try again to solve the problem before viewing another hint.

What is the locus of the midpoints of all the segments joining a vertex and the opposite side?

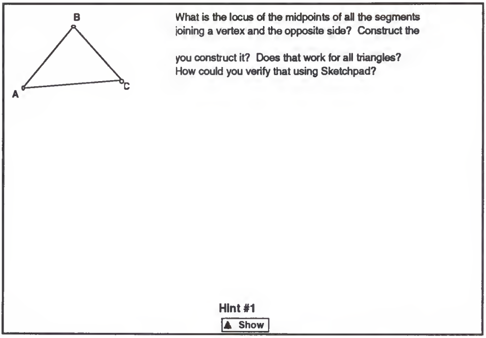
Construct the locus without using the Trace Locus command. How did you construct it?

Does that hold work for all triangles?

How could you verify that using Sketchpad?

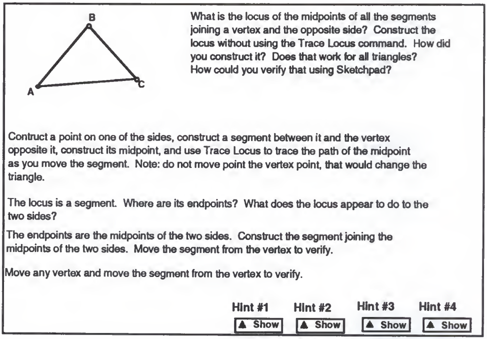
How did you use Sketchpad to solve the problems?

Which hints did you use?



What is the locus of the midpoints of all the segments joining a vertex and the opposite side? Construct the

you construct it? Does that work for all triangles? How could you verify that using Sketchpad?



What is the locus of the midpoints of all the segments joining a vertex and the opposite side? Construct the locus without using the Trace Locus command. How did you construct it? Does that work for all triangles? How could you verify that using Sketchpad?

Contruct a point on one of the sides, construct a segment between it and the vertex opposite it, construct its midpoint, and use Trace Locus to trace the path of the midpoint as you move the segment. Note: do not move point the vertex point, that would change the triangle.

The locus is a segment. Where are its endpoints? What does the locus appear to do to the two sides?

The endpoints are the midpoints of the two sides. Construct the segment joining the midpoints of the two sides. Move the segment from the vertex to verify.

Move any vertex and move the segment from the vertex to verify.

APPENDIX B
ATTITUDE TOWARDS THE GEOMETER'S SKETCHPAD SURVEY

Instructions

This questionnaire is designed to gather data on your attitudes towards using the Geometer's Sketchpad program to learn geometry. Please read each item and indicate the degree to which you feel that the statement is true of you. Read each response choice carefully and select the response that best expresses your feelings about the statement.

You will see the following responses below each statement with a circle next to it.

Strongly Agree
Agree
Undecided
Disagree
Strongly Disagree

Click the circle next to the desired response.

There is no time limit for completing the questionnaire. Try not to spend too much time on any one item. Your first reaction to the statement will probably be the most accurate.

Statements

1. If I couldn't solve a problem using Sketchpad, it was because I'm not familiar enough with how to use the Sketchpad program.
2. Sketchpad makes it easier to discover how to do things in geometry.
3. I can solve a geometry problem just as well or better without using the Sketchpad as I can using it.

4. I don't like using Sketchpad because it doesn't tell me what the answer is, I have to discover it for myself.
5. I understand geometry better when I use the Sketchpad.
6. I understand something better when I learn it using the textbook than when I use Sketchpad.
7. Learning geometry using Sketchpad is very different from learning geometry using a textbook.
8. I can solve a geometry problem better using the Sketchpad than I can without it.
9. I feel comfortable using the Sketchpad.
10. I think we should use the Sketchpad more often.

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BIOGRAPHICAL SKETCH

Robert Jan Melczarek was born in Brisbane, Australia, on February 3, 1956. He immigrated with his family to the United States in 1965 and has resided there since as a permanent resident alien, while still maintaining his Australian citizenship. Almost thirty years to the day after leaving, he went back to his homeland for a three week "pilgrimage." He graduated from Manatee High School and Manatee Junior College, located in Bradenton, Florida, in 1973 and 1974, respectively. He received a Bachelor of Arts in mathematics from the College of Natural Sciences at the University of South Florida. He completed his Master of Education degree in mathematics education at the University of Florida in 1979.

His career has included teaching educational technology and computer science courses at the University of Florida and teaching educational technology workshops for public schools in North Central Florida. He has also taught mathematics at the high school and community college levels, and computer science at the elementary and community college levels. His career also included software design and programming on the Science Helper K-8 and Culture and Technology CD-ROM projects as well as other educational projects.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Elroy J. Bolduc, Chairman
Professor of Instruction and Curriculum

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Mary Grace Kantowski

Mary Grace Kantowski
Professor of Instruction and Curriculum

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Mark Hale

Mark Hale
Associate Professor of Mathematics

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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December, 1996

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